AN INVESTIGATION OF THE INTERRELATION OF SOME OF THE DOMINATING VARIABLES OF A LAS SALINAS TYPE SOLAR STILL

JAMES H. BARRY

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Lieutenant, United States Navy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
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ABSTRACT

Solar stills similar to the type first built in Las Salinas, Chile, in 1872, are today the type which show the greatest promise for utilization of solar energy for the conversion of sea water to fresh water.

In this paper, a method of improving the efficiency of such a solar still by cooling the condensing surfaces with sea water is investigated. Results are negative in that by so doing the efficiency of the still is decreased.

A dimensional analysis provided a possible correlation of the yield of a solar still with the temperature of the water in the evaporating tray, and the temperature of the external glass surface. This correlation should prove useful in future efforts to design and operate solar stills at maximum efficiency, and might have applications in related fields of heat transfer.

The writer, with deep appreciation, wishes to thank Professors P. F. Pucci and C. P. Howard for their invaluable advice and counsel, and Mr. R. P. Kennicott for his assistance in the construction of the solar stills used in the investigation.

LIST OF SYMBOLS

A	Area, ft^2, also indicates Still "A"
B	Still "B"
Dv	Diffusivity ft^2/Hr
g	Acceleration, $4.17 \cdot 10^8$ ft/Hr^2
h	Coeff. of heat transfer $BTU/Hrft^2{}^\circ F$.
K	Thermal conductivity $BTU/Hrft^\circ F$.
L	Characteristic length; 3.915 feet
$\dot{m}$	Mass flow rate, lbs/Hr.
N	Dimensionless parameter, $\frac{C_p(T_r - T_s)}{\lambda} \cdot \frac{(P_r - P_s)}{gL\rho} \cdot \frac{\rho C_p D_v}{K}$
N'	Lumped constants and temperature variables of N, $= \frac{Cp(12)^3}{\lambda PLg} \cdot \frac{1}{\text{Lewis}}$
P	Vapor pressure (see subscripts)
Pe	Peclet number, $\frac{\dot{m}C_p}{KL} = 4.15\ m$
Q	Quantity of heat, BTU
q	Rate of heat flow BTU/Hr
T	Temperature, (see subscripts)
α	Some characteristic angle, radians
β	Coefficient of expansion 1/T
ϵ	Emissivity
λ	Latent heat of evaporation, BTU/lb.
μ	Viscosity lbs/Hrft.
ρ	Density, lbs/ft^3

Subscripts

a	Ambient and average. T_a indicates ambient temperature	
f	Film. T_f indicates film temperature $= \frac{T_t + T_g}{2}$	
g	Glass, external. T_{ga} indicates an area-weighted average external glass temperature for a still. P_g indicates saturated vapor pressure at T_g.	
n	North :	T_n indicates temperature of external
s	South :	glass surface of North side of still.
e	East :	P_n indicates the saturated vapor pressure
w	West :	at T_n. A_n indicates the North face of Still A.
t	Tray. T_t indicates temperature of water in the evaporating tray. P_t indicates saturated vapor pressure at T_t.	

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1. Introduction.

Almost from the time when it was considered a god, the sun has challenged man to use its boundless energy to perform some of man's many tasks. Scientists and homeinventors alike have produced endless devices to answer this challenge, but rarely have they become more than curiosities.

A similar challenge has come from the sea. That a desert, a potential garden land but for lack of fresh water, can exist by the side of a vast body of sea water is still a problem of world-wide import.

In 1872 man answered one of these challenges by means of the other. In Las Salinas, Chile, a solar sea-water distillation plant of over 6000 gallons a day yield was constructed, and it operated successfully for many years. Since that year countless varieties of solar stills have been suggested or built. However the Chilean-type stills, with certain improvements, maintain their position today as the type of solar still offering the best yield-to-cost ratio. (25)

The economics of solar energy present a paradox in that solar energy is "free", and the means are at hand to collect it, yet a solar solution to an energy problem is often the most expensive solution. Such is the case in the United States. Therefore, although there are indications that the sea will (and possibly must) begin to supply some of our fresh-water needs, the energy source will probably not be solar. The reason for this is twofold. First, the cost of the equipment per gallon a day collected, and secondly, the amount of land area required. It is estimated by Lof (25) that the lowest ultimate cost per 1000 gallons of solar water in this country will not

be less than one dollar, which compares poorly with the present five cents to twenty cents per 1000 gallons from municipal sources. The average intensity of solar radiation in this country is 1500 BTU/day, ft^2. (25). If a solar still operates at 60 percent efficiency, about ten square feet of collector area are required for each gallon per day produced. A community area the size of the Monterey Peninsula would then require roughly 1800 acres of stills to supply its needs. If multiple effect distillation were employed, this last figure could be quartered, but the cost per 1000 gallons would be trebled. (26)

Despite the above conjectures on the future of solar distillation in our own country, in other countries where labor conditions, material and land availability are far different than in our own, a solar distillation is looked upon as a method holding great promise (9).

The Las Salinas-type Still.

The Las Salinas-type still can be most easily described as resembling a long pup tent, with glass ends and roof, oriented so that the ridgepole is pointed East and West. A thin layer of sea-water is held in a dull black tray - the floor of the tent.

Glass has unique properties that specially recommend it to uses involving solar heat collection. It is almost completely transparent to radiation of the solar wave lengths, absorbing, dependent on impurity content, as low as one percent of the total incident energy. Reflection losses are higher, being about eight percent of the incident energy for a beam normal to the glass. However, glass is virtually opaque to radiation from surfaces below 300° to 400° F., and in this region has an emissivity of about .96.

Therefore, depending on incidence angle, up to 91 percent of the sun's energy is transmitted to the collector tray of the Las Salinas still, which can reach a temperature of 140° - 180° at midday. Re-radiation from the tray is determined only by emissivities and the temperatures of the water in the tray and the glass roofs. This is about ten percent of the incident energy. Water, evaporating from the tray, condenses on the sloping glass roofs (which are generally 25° - 30° F. cooler than the tray at midday), and is collected. In cooling these condensing surfaces, radiation to the sky and natural convection are equally important; wind is more important than either. This perhaps can be best illustrated by the heat balance included in appendix (1). Although the amount of incident radiation was not measured, it is believed the figures are approximately correct.

Maximum yield that has been reported for such a still is .18 gallons

a day per square foot of tray surface (Algeria). This varies with latitude and ambient conditions such that the maximum reported yield in this vicinity is one-tenth gallon per day per square foot of tray surface (Berkeley).

2. Equipment and Instrumentation.

Construction.

The solar stills used in this investigation are of the Las Salinas type. Since no method of measuring the incident energy was at hand, two stills were constructed of exactly equal description, one to be used as a standard (henceforth called Still "B"), measuring the effect of alterations to the other (henceforth called Still "A"). They have a tray dimension of 47" x 47". The glass roofs and ends are three-sixteenths-inch window glass, the roofs sloping at an angle of 45°. The bottom of the still was covered with a sheet of one-eighth-inch press-board. A two-and-one-half-inch thick fiber glass blanket lies between this bottom and the tray. The frame of the stills is redwood, and all joints, both wood-wood and wood-glass were sealed with Pabco Hydroseal. The galvanized sheetmetal tray was painted with Sherwin Williams dull black Enameloid.

Figure 1 shows the general appearance, and indicates the more important dimensions of these stills. Figure 2 is a photograph of the actual installation.

The water level in each still was adjusted so that the evaporating tray held 40 lbs. of water. This was the minimum amount that would prevent some portion of the trays from being exposed toward the end of the day. The depth of water varied, due to tray buckling, from one-fourth to three-fourths inches. Condensate was collected from each condensing surface separately. Collecting troughs, milled into the redwood frame of the stills below the condensing surfaces, carried the condensate to external collecting bottles.

Since data was to be comparative, no attempt was made to design

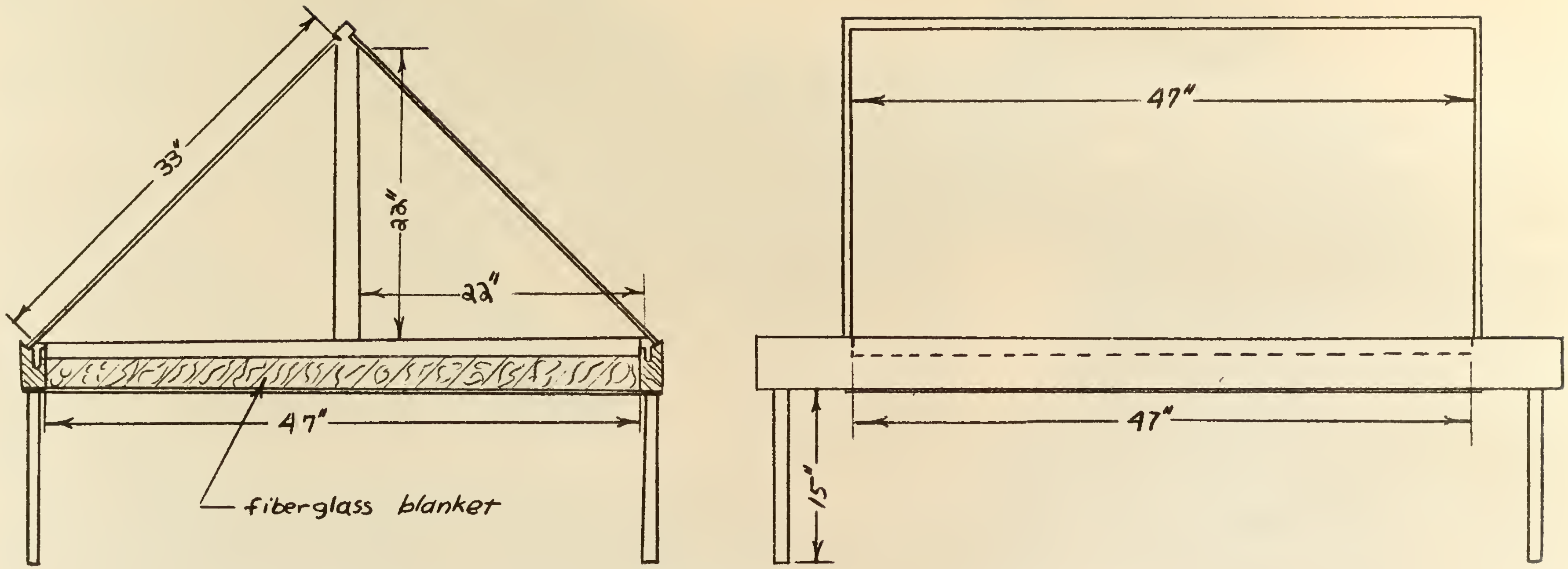

FIGURE (1) GENERAL APPEARANCE OF SOLAR STILLS USED IN INVESTIGATION, SHOWING PRINCIPAL DIMENSIONS OF EVAPORATING TRAY AND GLASS CONDENSING SURFACES.

Figure (2)

the stills for maximum efficiency. Available glass with a greenish tinge (indicating presence of iron) was used. Likewise it is possible that a thinner glass could have been used with some efficiency increase. The length to width ratio was not as large as desirable, but this perhaps increased the overall efficiency due to a better angle of incidence in the afternoon.

Still "A" was modified to permit cooling the North and South condensing surfaces with water.

Two tanks of combined capacity of 70 gallons were used as insulated storage tanks. One sheetmetal tank of equal capacity was used as a receiving tank for the cooling water discharge and for the water used to flush the stills. Painted black, it was also used as a radiator to cool the cooling water each night. In the morning the water, at a temperature of 48° - 55° F., was drained into the insulated tanks where it was available for further cooling purposes. Pressure on the cooling system was maintained by a small air compressor.

Water from the pressurized tanks was regulated by needle valve and sent to Still "A" by insulated one-fourth inch Saran Tubing. At the still it was sprayed over one or both of the sloping faces from three-eighths-inch Saran Tubes fixed across the top of the North and South faces. Several methods of evenly distributing the water were tried. Small holes spaced evenly the length of the tubing were unsatisfactory, due to clogging. The method finally used was to slit the plastic on one side the full length of the glass and then insert a felt strip two inches wide into the slit. With this method the system was non-clogging and could be evenly spread across the top of the glass. However, the flow tended to concentrate into streams, and at about midway down

the glass only about 25 percent of the glass was covered by the water. Had the method been successful in increasing yield, a better means would have to be found to distribute the cooling water.

There were also filling and discharge lines leading to each still to enable flushing. Both flushing and cooling could be regulated to occur at any desired tray temperature by means of Solenoid Valves operated by a thermostat beneath the tray of Still "A".

Comments on Construction.

(1) It is felt that Hydroseal is not an ideal sealant since it imparts a strong, unpleasant taste and aroma to the water.

(2) It is felt that a still can easily be designed which will minimize the need for sealant by recessing the glass edges in grooves, and by careful attention to the design of the lower edge joint. Figure (3) shows the type of joint used in subject stills, which is considered to be improper; and shows a better type of jointure which would minimize leakage and the contact of the condensate with the sealant.

Location of Stills.

The stills were located on the roof of a three-story building at the U. S. Naval Postgraduate School, Monterey, California. Trees in the area to the North and East provided a wind break so that during the investigations described the local wind was rarely above seven knots. The stills, however, had a clear view of the sky in all directions with one important and awkward exception: one tree was so located that after 15 March Still "B" did not clearly see the sun until 0820, and Still "A" untill 0840.

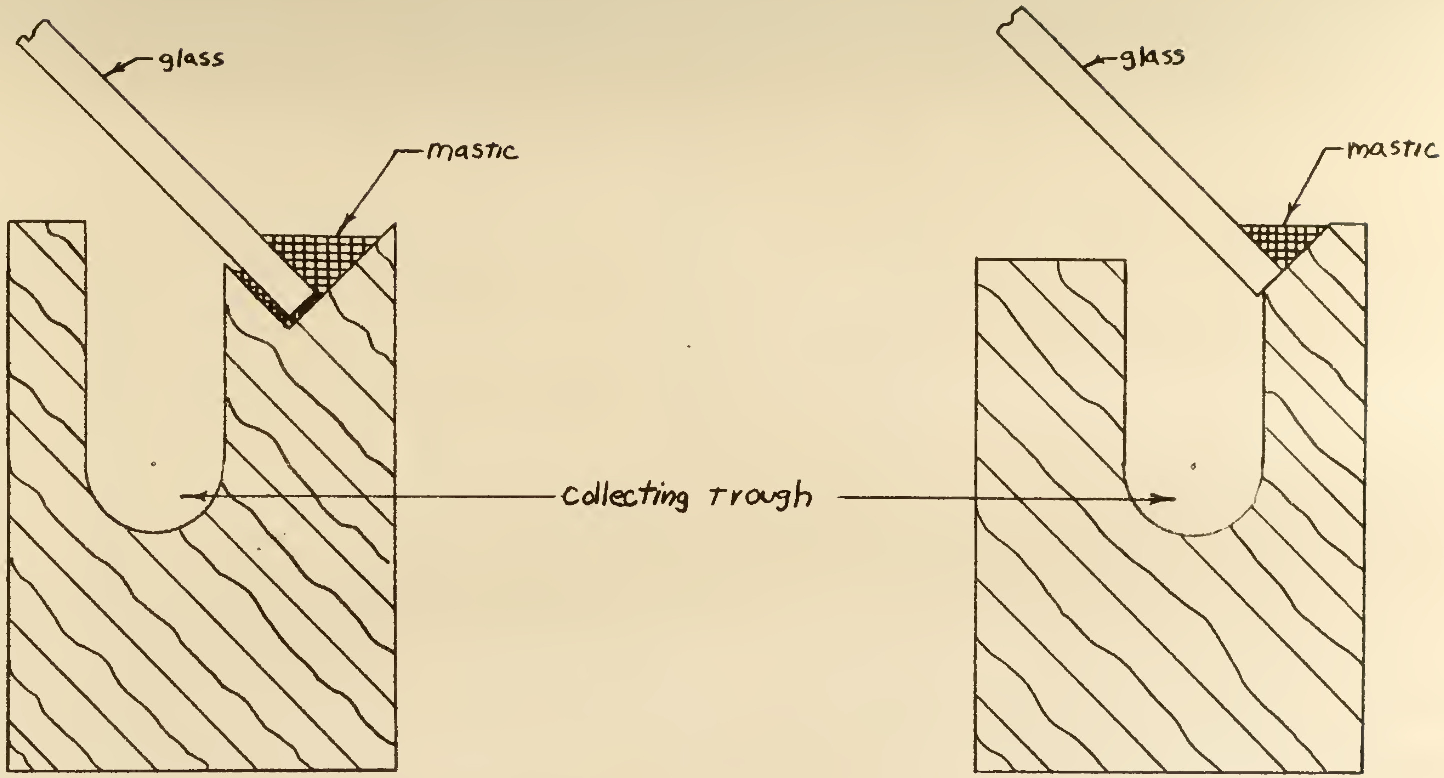

FIGURE (3) IMPROPER (LEFT) AND SUGGESTED METHOD FOR JOINTURE OF LOWER EDGE OF GLASS CONDENSING SURFACE TO THE WOOD FRAME OF A SOLAR STILL.

The trays were about 15" above the rooftop. Still "A" was ten feet East of Still "B". Both were oriented so that the sloping roofs were facing North and South.

Instrumentation.

Both stills were equipped with copper-constantin thermocouples to enable recording of the following temperatures:

Tray temperature;	thermocouple soldered to center of tray.
Water temperature;	three-sixteenths-inch from water surface, near tray center and where water was one-half inch deep.
Vapor temperature;	inside aluminum radiation shield at west end of stills, midway between ridge and tray.
Glass temperature,	exterior; centered on the North and South faces and centered on the South triangle of each East and West face.

Cooling water ("In" and "Out"); Still "A".

Ambient air temperature.

Even though thermocouple terminal boards were at similar locations on the West end of each still, and shielded from the sun, it was found that temperature of these boards varied as much as four degrees; and that initial use of only one ice junction, at Still "B", caused temperature errors of the same magnitude due to secondary thermocouple effect at these boards.

Three terminal boards were required at each still and eventually each therminal board was connected to an individual ice junction.

Temperatures were recorded upon a Honeywell Multiple Point Recorder using a constant-balance type of circuit.

Millivolt readings could be accurately taken to the second decimal place, with the third place estimated. The recorder was located in a third-floor room and connected to the thermocouple terminal boards by 30-foot copper leads.

Wet and dry bulb temperatures were taken hourly during test runs with a sling psychrometer. Wind readings were similarly taken at a point between the two stills using a hand-held anemometer, U. S. Navy, type AN/PMQ-3. (Made by Bendix Corp.)

Comments upon Instrumentation:

(1) Additional foresight would have dictated placing thermocouple terminal boards on North side of stills where shielding from the sun would have been less difficult.

(2) Unfortunately the temperature information cannot be viewed with complete confidence, since toward completion of the investigations described, evidence was found of ground looping between the tray and water thermocouples. Maximum errors occured at midday, and it is believed that in some cases they approached two degrees. Final runs were made with the tray thermocouple disconnected, giving better results.

(3) Since several investigators have reported difficulty in finding a method of attaching thermocouples to the glass surfaces of the still, the following description of the method used is included:

After numerous failures involving Du Pont and Glyptal cements, Glyptal varnish, Armstrong epoxy resin cements and several plastics a

method was adopted that produced a lasting and what is believed to be firm connection between thermocouple bead and the external glass surface. A small cube of rubber weatherstripping, one-fourth inch on a side, was coated with Goodyear Pliobond to waterproof it. Then a small piece of aluminum foil about five-thirty-seconds inch square was centered on one face of the cube. Pliobond was applied to the periphery of this face and to a spot on the glass, leaving a bare center on each where the thermocouple bead was to sit. With the bead in the glue-free center, the cube was pressed onto the glass and taped down to provide pressure while the glue dried. Once dry, the tape was removed and excess glue was scraped off the glass. This type of installation has withstood many rains and nightly dews without loosening. Not only is the bead held firmly against the glass by the elasticity of the rubber, but the aluminum square firmly hugs both the bead and the glass, giving an effectively increased contact area. The thermocouple is also shielded from the sun's radiation. It was initially assumed that, although the rubber cube insulates the contact area of the glass from the air, temperature equalization occurs to the sides to a satisfactory degree. A subsequent examination by relaxation plotting (with conservative assumptions) showed that for a solar input of 265 BTU/ft^2 hr. the thermocouple should read about four-tenths of a degree higher than the actual glass temperature, and the discrepancy is believed to be actually much less than this.

(4) The assumption that one thermocouple placed at the center of a glass face would give an acceptable mean temperature for that face is considered to be valid, since measurements with a thermocouple similar

to that described in 3 above, but mounted on a hand probe, showed variation across a glass face in the horizontal and vertical direction to be in the order of two-tenths of a degree.

3. Experimental Procedure, General.

The investigation can be discussed under three interrelated but separate topics:

a) Observations to determine relative performance of each condensing surface in respect to yield, and the performance of Still "A" relative to Still "B" under normal operating conditions.

b) Observations to determine the effect on the yield of Still "A" of changing the heat transfer conditions of the condensing surfaces.

c) Observations to determine the relation of the yield of the condensing surfaces to the dependent variables of tray water temperature, and external temperature of the glass condensing surfaces.

Certain experimental procedures were common to each of the above phases:

a) Until 15 March, the stills were flushed automatically during the night, and the measurements of yield were made on the basis of a 24-hour run. However, by March 15, the sun had moved northward enough to cause the aforementioned tree shadow to fall across the stills. Still "A" did not clearly see the sun until 0820, and Still "B" until 0840. This unavoidable shielding necessitated starting comparison tests after this date at 0900, and made exact duplication of initial conditions in each still difficult. This was achieved as closely as possible by a combination of flushing both stills and covering Still "B" with a tarpaulin

between 0820 and 0840. By May 13 the shadow crossed the face of the stills at approximately the same time and for an equal period, at 0730 PST and no equalizing procedure was required on that date.

b) All daily yield measurements were made with a spring scale at 0800.

c) On days when the mass flow rate was determined, yield measurements were made at 30-minute intervals, using a 500 or a 100ML graduate. These measurements were converted to mass flow rate, using central differencing methods, by means of the following numerical differentiation formula (3),

$$12hD = Y_{(i-2)} - 8Y_{(i-1)} + 8Y_{(i+1)} - Y_{(i+2)}$$

For easy application this formula was converted to

$$12h\dot{m} = -\nabla_{(i-30)} + 7\nabla_{(i)} + 7\nabla_{(i+30)} - \nabla_{(i+60)}$$

where: $\dot{m}$ = Mass flow rate, lbs hr at time

h = interval between measurements = 1/2

$\nabla_{(i)}$ = the 1st backward difference, = amount (lbs) of condensate produced during the 30-minute period preceding time (i), similarly $\nabla_{(i+30)}$ = amount of condensate produced during the 30-minute period preceding time $(i + 30)$.

This formula should produce errors of the order h^4.

d) Temperatures were also recorded at 30-minute intervals.

e) For convenience, fresh water was used both for cooling

water and for the distilling trays.

It is considered that the results would not be affected by this procedure.

4. Observation to determine relative performance of each condensing surface, in respect to yield, and the performance of Still "A" relative to Still "B" under normal conditions of operation.

During the period of the investigation, yield measurements were taken with both stills operating under as nearly identical conditions as possible. These measurements were used as a basis for comparison when alterations were made to the characteristics of Still "A", and also to determine the relative capability of the various condensing surfaces.

No experimental procedures were employed other than those outlined in the preceding section.

Results.

Table (1), Appendix 2 is a compilation of the above measurements.

Figure (4) shows typical temperature and yield curves for Still "A", plus the water, glass and ambient temperatures. The values for Still "B" are indicated where they differ from those of "A", but in interest of clarity, the curves are not drawn.

Interpretation.

(1) The East and West vertical faces make important contributions to the yield of these stills, due to a L/W ratio of one, but in a production-model still the L/W ratio is so large (25-100) that yield of the ends is insignificant.

(2) The South face, since it absorbs 1-2 percent of the incoming radiation, is usually several degrees warmer than the North face, and consequently could be expected to be a poorer condenser.

(3) The overall yield coeff. (Yield A÷ Yield B) can be taken as one when operating under similar conditions.

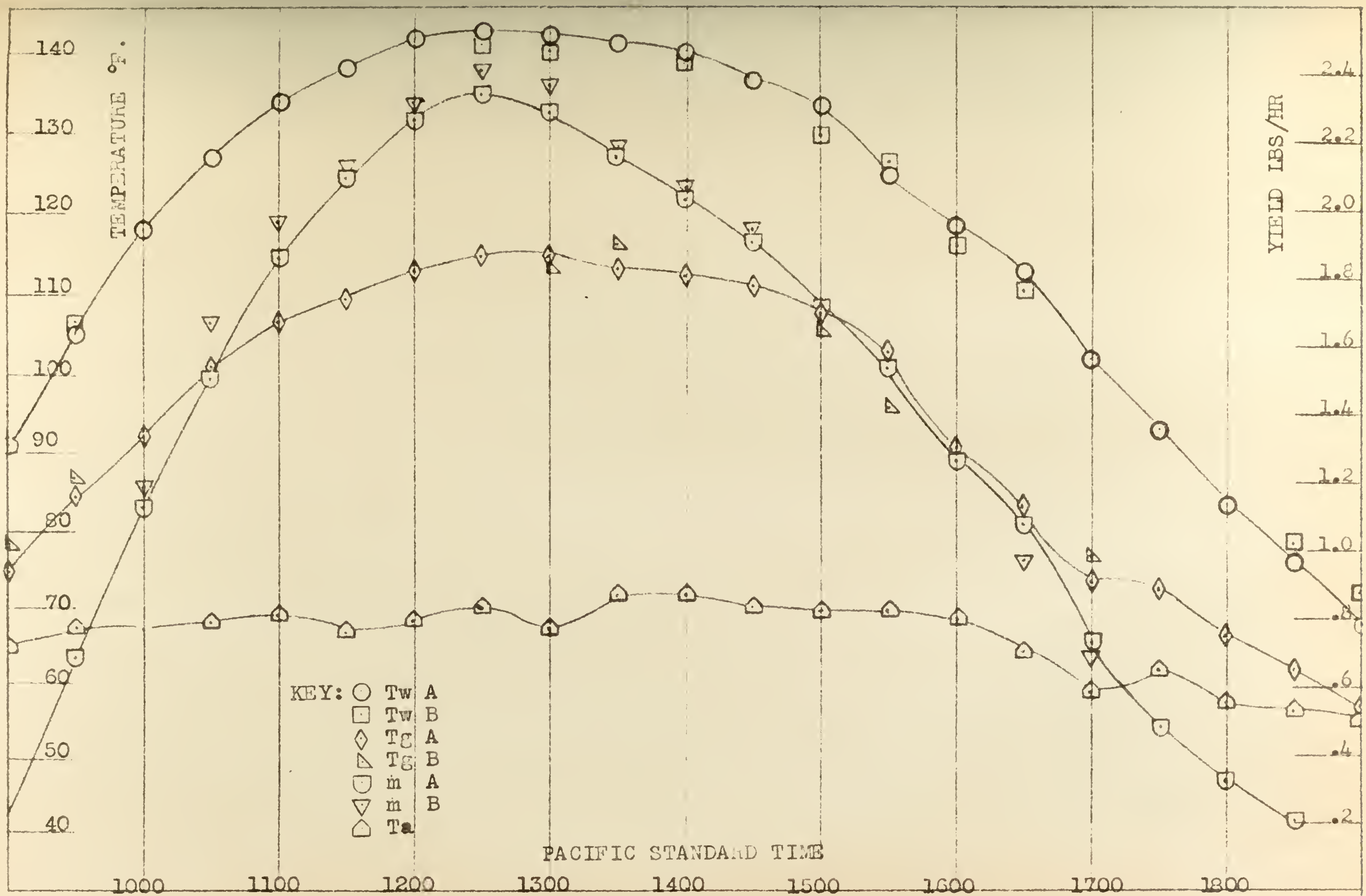

FIGURE (4) TEMPERATURE AND YIELD CURVE 19 APRIL, 1958

(4) The drop to a coeff. of about .97 on 22 March and 19 April is assumed to be an indication that the inequality due to the aforementioned tree shadow was not completely neutralized.

(5) The variation of effectiveness of the condensing surfaces and the variation of the yield coeff. on the various days listed is also influenced by wind direction. Winds were generally variable in the morning, and increasingly westerly in the afternoon.

5. Observation to determine the effect on the yield of Still "A" of changing the heat transfer conditions of the condenser surfaces.

Discussion.

The form of the Carnot efficiency equation $e = \frac{T_1 - T_2}{T_1}$ indicates not only that efficiency increases as ΔT increases, but also that a drop of X degrees in T_2, will increase efficiency more than a similar rise in T_1 since: $\frac{\partial e}{\partial T_1} = \frac{-T_2}{T_1} \frac{\partial e}{\partial T_2}$

Likewise with solar energy collectors in general, the efficiency rises as collector temperature decreases, since radiation reception is increased and losses are decreased.

Work by Howe (19) has indicated that the greater portion of any energy which may be stored in a solar still at sundown by reason of its heat capacity is not regained in the form of yield, so that reduction in the overall temperature of a still seems advantageous in this respect.

The enthalpy of saturated vapor decreases slightly as temperature decreases:

At 100°F. hfg = 1037.2; hg = 1105.2

At 150°F. hfg = 1008.2; hg = 1126.1

Howe (19) observed that under conditions of low wind velocities and with high incident energy that yield is markedly curtailed. He found that in one series of tests the maximum yield with no wind on a June day was .05 gallon per day per ft^2, while with wind speed above nine knots the yield on a similar day was .1 gallon per day per ft^2.

Fitzmaurice and Seligman (16) state, "We think that there is an appreciable drop in efficiency due to the escape of vapor at the

vents. As a corollary of this we assume that evaporation is ahead of condensation, and to work at true atmospheric pressure it will be necessary to find balance between evaporation and condensation such that the pressure buildup is negligible."

The above facts and observations seem to indicate that advantages should incur if the condensing capabilities of solar stills could be improved. Such increased capabilities would decrease the overall still temperature, and lower the vapor pressure.

Since such stills are usually oceanside affairs (greatest exception, Australia, where brackish well-water is distilled), it seems possible to use the sea temperature as a sink rather than ambient air. Although this has been proposed in connection with multiple-effect stills using focusing collectors, it has not been utilized with stills of the Las Salinas variety to writer's knowledge.

Although the economic factors involved in the additional pump work that would be required have not been explored, it is noted that Eibling (26) indicates that high capacity multiple-effect stills using focusing collectors should have intermingled flatplate collector stills in order to fully utilize the "sun space". In an installation of this type, the cooling water for the Las Salinas still could provide feed for the multiple-effect stills.

Procedure.

To test the above idea, that is, to increase the condensing capabilities, Still "A" was modified as previously noted to allow cooling the North and/or South condensing surfaces with water, and comparisons were made with the unaltered still.

Water at a temperature of 50° - 60°F was allowed to flow over the external condensing surfaces. The rate of coolant flow varied on various days, but no quantitative measurements were made of the effect of this variation. Likewise, although the temperature of the coolant "to" and "from" was measured, no quantitative use of these measurements was made.

Results.

Although the overall temperature of the still was lowered, and although the condensing capabilities were increased, the results were in all cases negative, in that the resulting yield coeffcients were lower than when "A" was not cooled. Table 2, Appendix 2 indicates the compiled results of these tests. Figures (5) - (7) show representative temperature and yield relationships for these tests. Only in the first hours of a test run, when the temperature of the water and the glass surfaces of a normal still are too close together to provide condensing potential, did artificial cooling produce any increased yield.

Interpretation.

In establishing the reason for failure of external cooling to produce improved yield, it might be constructive to establish which factors cannot be causitive.

For this purpose, an analysis is made of the possible losses at 1200 on 11 April, when both North and South faces of Still "A" were cooled.

Conditions at that time were as follows:

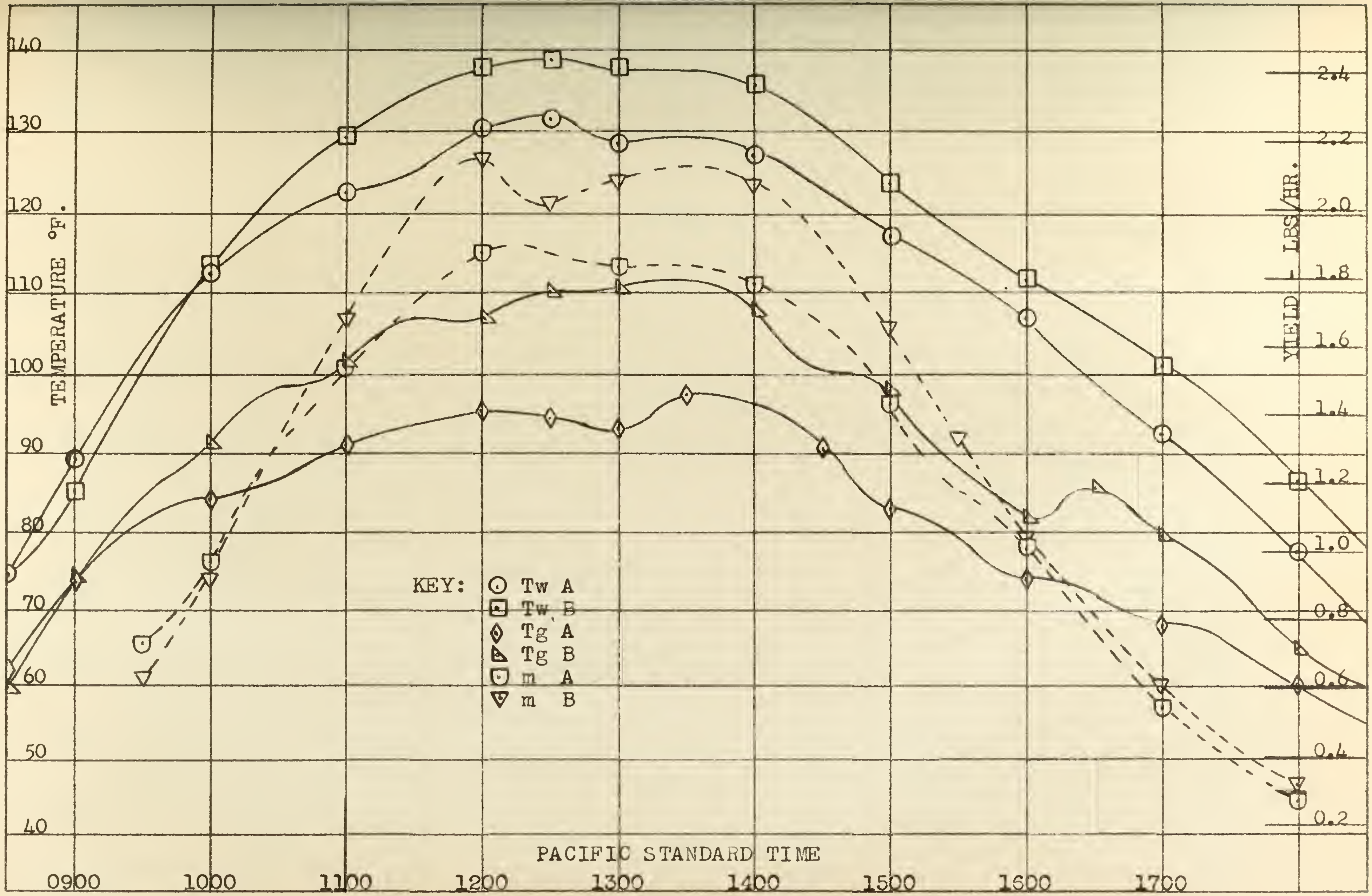

FIGURE (5) TEMPERATURE AND YIELD CURVES FOR 10 APRIL, 1958
As COOLED.

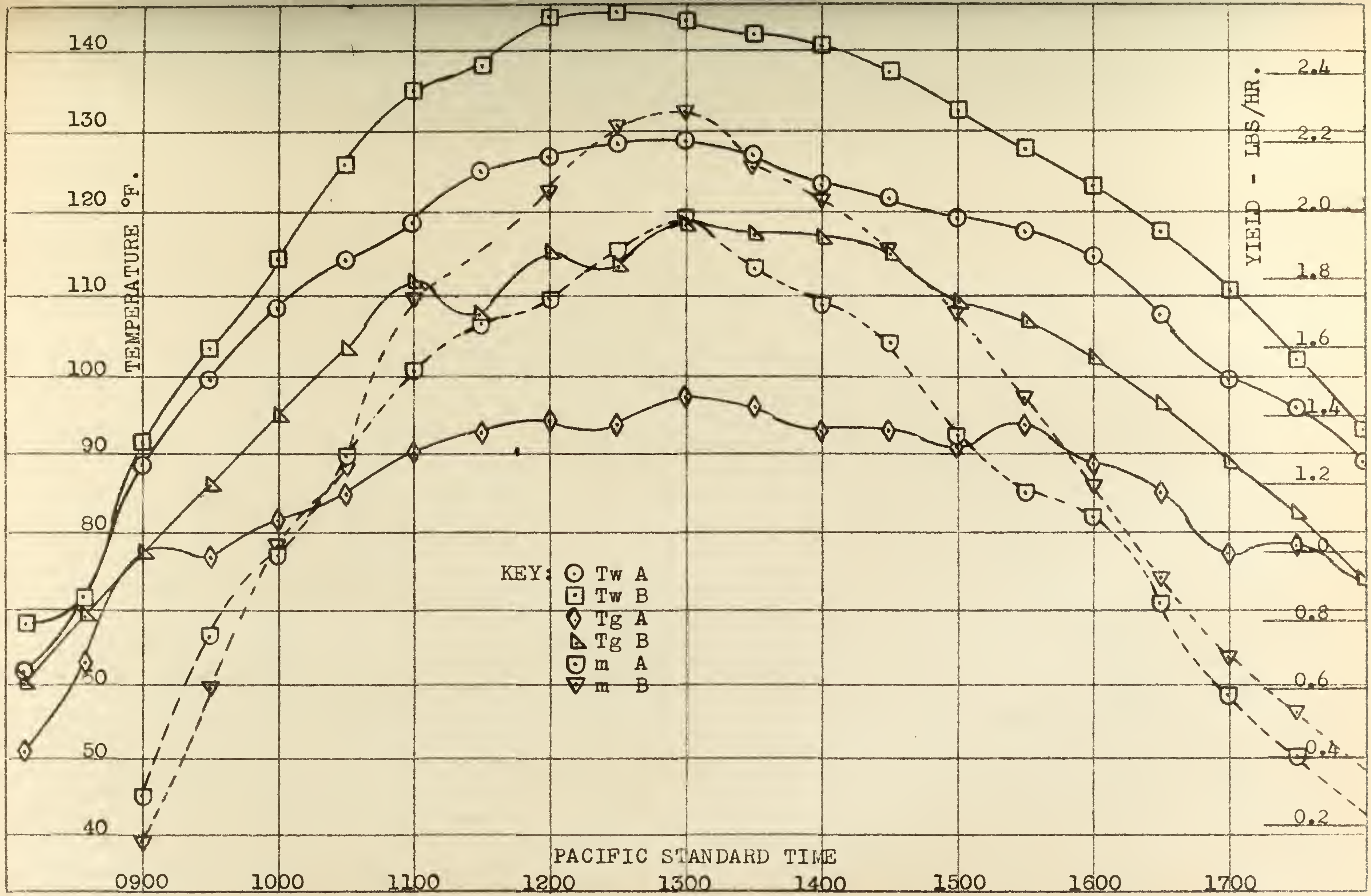

FIGURE (6) TEMPERATURE AND YIELD CURVES FOR 11 APRIL, 1958
An and As COOLED.

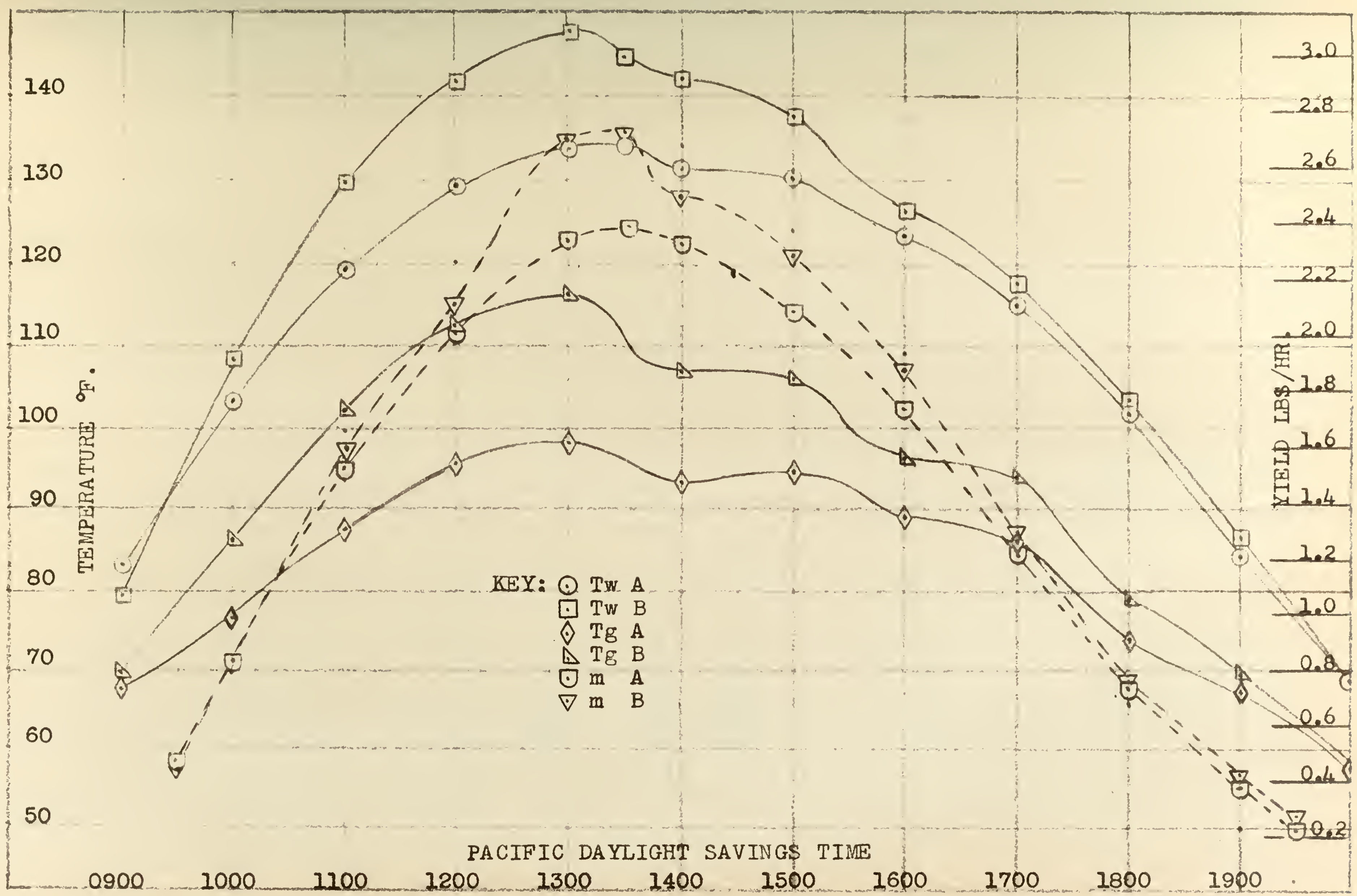

FIGURE (7) TEMPERATURE AND YIELD CURVES, 13 MAY, 1958; An COOLED.

	Still "A"	Still "B"
Tt	127°F	144.5°F
Tn	91	115
Ts	95	117
Te	98.5	112
Tw	98.5	112
Tg, average	94	115
$\hat{m}$	1.738	2.055
T ambient	78.5	78.5

$\hat{m}A \div \hat{m}B$ .845

Emissivity, glass and water .96

Radiation.

Radiation between collector and glass furface Still "A"

$$\frac{q}{A} = \frac{\sigma\left(T_T^4 - T_g^4\right)}{1 + \left(\frac{1}{\epsilon_{water}} - 1\right) + \frac{A_T}{A_g}\left(\frac{1}{\epsilon_{glass}} - 1\right)}$$

$$= .939 \; (.1713 \times 10^{-8}) \; (587^4 - 554^4) = 38.6 \frac{BTU}{HrFt^2}$$

Radiation between collector and glass surface of Still "B" similarly:

$$\frac{q}{A} = .939 \; (.1713 \times 10^{-8}) (604.5^4 - 575^4) = 39.4 \frac{BTU}{Hrft^2}$$

Assuming approximate insolation of 200 BTU/Hr ft^2 this becomes $\frac{.8}{200}$ or roughly .005 percent <u>increase</u> in efficiency for the cooled still over the uncooled.

While the above value tends to shift to the favor of the uncooled still when the sun is further from the meridian, the shift is small, and the above figures seem to indicate that radiation is not the cause for the discrepancy in yield.

Conduction.

Conduction losses, Still "A" (Considering conduction from tray through bottom of still only)

$$\frac{q}{A} = \frac{K(Tt - Ta)}{X}$$

K of fiberglass = .024
X = 2½" = .208 feet

$$= \frac{.024(127 - 78.5)}{.208} = 5.6 \text{ BTU/hr ft}^2$$

Still "B"

$$\frac{q}{A} = \frac{.024(144.5 - 78.5)}{.208} = 7.62 \text{ BTU/Hr ft}^2$$

or an approximate <u>increase</u> in efficiency of $\frac{2}{200}$ or one percent for the cooled still over the uncooled.

Absorption.

It was assumed that the absorption of insolation by the thin layer of water would not be excessive, although absorption spectrum for water rises steeply in the infra-red region. Overall absorption coefficients for the absorption of the sun's energy by water are not readily available. Sverdrup (1) gives an overall extinction coefficient for sea-water at the surface of .944. Since by the definition of extinction coefficient, this is equal to the absorption coefficient at the surface this value was used. Sverdrup also indicates that the value for pure sea-water is not markedly different from that of fresh water.

The maximum thickness of the water film did not exceed 2mm. We therefore have:

$$I_L = I_0 e^{-.944L}; \quad I_L = I_0 e^{-(.944)(.002)} = .998I_0$$

which indicates that absorption is not an important factor.

Reflection.

No quantitative estimate of reflection losses was made. The water film, it is believed, did contribute to extra reflection losses due to the rippling of the film, particularly on the lower half of the glass surface. The water film in this area caused a discernable shadow to be cast upon the water in the evaporating tray. However, particularly since at most only 40 percent of the glass surface was covered with the cooling water film, this extra loss is not considered to be the predominate reason for the .845 yield coefficient.

Therefore, assuming that the above items are not the dominating factors in the reduction of the yield coefficient, the convection process must be examined more fully.

That convection losses from the water to the condensing surfaces in the cooler still must be greater than in the warmer is evident upon examination of the mixture ratios of the air-vapor mixture within the stills:

Still "A" $$Tf = \frac{Tt + Tg}{2} = \frac{127 + 94}{2} = 110.5$$

$$Pvapor = 1.293 \quad (27)$$

$$Pair = 14.696 - 1.293 = 13.404$$

$$\frac{\rho\,vapor}{\rho\ air} = \frac{1.293 \times 18}{13.403 \times 29} = .05975$$

Still "B" $$Tf = \frac{Tt + Tg}{2} = \frac{144.5 + 115}{2} = 129.75$$

$$P_{vapor} = 2.209 \quad (27)$$

$$P_{air} = 14.696 - 2.209 = 12.489$$

$$\frac{\rho_{vapor}}{\rho_{air}} = \frac{2.209 \times 18}{12.489 \times 29} = .1097$$

$$\frac{\text{Mixture ratio "A"}}{\text{Mixture ratio "B"}} = \frac{.05975}{.1097} = .544$$

The gross assumption must be that twice as much air must be circulated in Still "A" in order to condense an equal amount of water, with attendant greater convection losses due to sensible heat transfer from the air mass.

In the extreme cases, of course, mixture ratio of zero would mean maximum convection losses, while with a mixture ratio of infinity convection losses would be minimum. The cases in between, however, are not so patent and will be examined more carefully in the next section of this paper.

6. Observation to determine the relation of the yield of the condensing surfaces to the dependent variables by traywater temperature and external temperature of the glass condensing surfaces.

A solar still involves simultaneous evaporation and condensation of a vapor in a mixture of vapor and a noncondensable gas, together with convection, radiation and conduction heat transfer. Although each field has been subject to much investigation, the combination, occuring in a closed chamber of the geometric shape of a Las Salinas Still, to the writer's knowledge, has not been so investigated.

In an effort to establish the relationship between the yield of a solar still and the condition existing in the still, it was decided not to attempt force-fitting solutions to above individual proglems upon the still, but rather to find such a relationship using easily measurable variables and not involving trial and error methods particularly found in existant solutions of the condensation problem.

The main factors influencing this decision were:

a) The condensation phase of the problem definitely involves both film and dropwise condensation. Any analytical solution would have to include a subjective measurement of the relative influence of both.

b) The convection process within the still is complicated both by geometry and because of the dual "potential" of a heated surface and a cooled surface within an enclosed space. The convection currents do not fully fit any of the standard flat plate free convection assumptions. In this connection physical observations of the convection pattern within solar stills are extremely interesting and easily made.

In the late afternoon, between 1630 and sunset, if an observer looks

into a still from the East side with his eye close to the edge of the glass side, he will observe a current of tiny water-vapor particles in rapid motion moving about the still. These are made visible by the reflection of the sun at that hour and are invisible at any other time. So clear is the presentation that these particles can actually be observed forming, or evaporating, as they move toward a warmer region of the still. The convection patterns observed are indicated in Figure (8). It is emphasized that this current is rapid, and bears no resemblance to the slow rise of vapor from heated pan of water on a cold day.

The decision referred to above having been made, a standard dimensional analysis was made. The following variables were considered:

$$\mu, \dot{m}, K, h, \rho, \alpha, \epsilon, C_p, P, T, g, L, Q, D_v, \lambda, \beta.$$

The following nondimensional parameters were obtained:

$\dfrac{gL^3\rho^2\lambda}{\mu K \Delta T}$ Nussult Condensation Number

$\dfrac{hL}{K}$ Nussult Number

$\dfrac{\dot{m}C_p}{KL}$ Peclet Number

$\dfrac{Q}{PL^3\lambda}$

$\dfrac{PA}{\mu D_v}$

$\dfrac{K}{\mu\lambda\beta}$

$\dfrac{\mu}{\rho D_v}$ Schmidt Number

$\dfrac{gL^3}{D_v^2}$

$\dfrac{\mu C_p}{K}$ Prandtl Number

α
ϵ

The parameters α , ϵ , while important in the design of a solar still, are not variable within a certain still, therefore these parameters are discarded.

Although the condensation number finds its application in the problem of condensation of pure vapor, it was thought that the relationship might be extended to include a gas-vapor mixture. Therefore, an attempt was made to correlate this parameter to the Peclet number. All properties were evaluated for water at a film temperature which was the average of Tt and Tg. The ΔT used was Tt - Tg.

It was found that no correlation existed, and this should have been expected since the important properties of vapor pressure and mass diffusivity are not included.

A search among other standard heat transfer parameters failed to locate one which seems to fully fit the conditions existing in a solar still. Conspicuously absent are those containing a pressure term.

It was considered that such a parameter must reflect temperature and pressure conditions and account for diffusivities. To that end the parameter $\frac{PA}{\mu D_v}$ was combined with the condensation number to obtain $\frac{gL\rho^2\lambda D_v}{KP\Delta T}$. This parameter was then separated into the following dimensionless parameters: $\frac{\lambda}{C_p\Delta T}$. $\frac{\rho C_p D_v}{K}$. $\frac{gL\rho}{P}$

These terms can be considered as follows (7):

I. $\frac{\lambda}{C_p\Delta T}$ = $\frac{\text{Latent Heat}}{\text{Sensible Heat Exchange}}$

II. $\frac{\rho C_p D_v}{K}$ (Lewis #)$^{-1}$ = $\frac{\text{Mass Diffusivity}}{\text{Thermal Diffusivity}}$

III. $\frac{gL\rho}{P}$ = $\frac{\text{Gravitational Forces}}{\text{Pressure Forces}}$

Since mass transfer is perpendicular to gravity flow, the mass transfer then should be inversely proportional to the ratio III as it is written, therefore, to obtain direct proportionality III was inverted. Similarly, mass transfer should be inversely proportional to I as written, so I was also inverted.

The parameter then becomes $\frac{C_p\Delta T}{\lambda} \cdot \frac{\rho C_p D_r}{K} \cdot \frac{P}{gL\rho}$ = N.

The value of Lewis number for saturated air vapor mixtures has not been fully established, but reported values in the region 60°F to 150°F vary from .81 to .91. The variation with temperature over this range is slight and confined to the third decimal place. Therefore a constant value of .866, reported by Hilpert was used.

In initial efforts to obtain correlation with this parameter, P and ρ were evaluated for saturated steam at Tf. The pressure parameter then becomes $\frac{RT}{gL}$. No correlation with Pe could be obtained.

As finally employed, all properties of I and III are evaluated as air-vapor mixture properties at Tf and II is evaluated as $\frac{1}{.866}$. Pressure was interpreted as $\Delta P = P_t - P_g$.

The characteristic length was the length of the North or South glass condensing surface (47 inches). The parameter N is most easily computed in the form $N = N' \Delta T \Delta P$ where N' contains all the constants and the temperature variable fluid properties.

Pe was similarly evaluated for mixture properties and becomes 4.15 x $\dot{m}$.

In Figure (9) are plotted the results of final correlation attempts.

While only runs for two different days have been plotted, it is considered that due to the varied nature of the conditions imposed, that these results show definite correlation. Since correlation was obtained in the final hours of this investigation, the writer was unable to examine dates other than those plotted. It is fully believed however that data on other dates would correlate. On this plot each of the North and South condensing surfaces was separately considered. They will henceforth be termed An, As, Bn, Bs.

These two dates were chosen since on these two dates it is considered that the best temperature information was obtained (the ground looping of thermocouples on prior dates was previously mentioned). On 29 April both stills operated under similar normal conditions. The sky was completely overcast with exception of the period 1530 - 1700.

On 13 June the North face of "A" was cooled, and reflects a correspondingly increased yield, while the uncooled South face of "A" reflects a decreased yield.

In Figure (10) the average Pe and N parameters of the North plus South faces are plotted. This plot still does not account for the full $\dot{m}$ of the stills, since the East and West faces are neglected. Since Pe presents yield in the form of $\dot{m}$ per foot of length, it was not considered advisable to include the triangular ends.

No plots of Still "B" for 29 April could be included due to lack of data for Bs.

Data and computation sheets for these dates are included in Appendix 3. Also included are plots of Vapor Pressure vs. Temperature in millivolts and for N' vs. Temperature in millivolts, which were used in calculating parameter values.

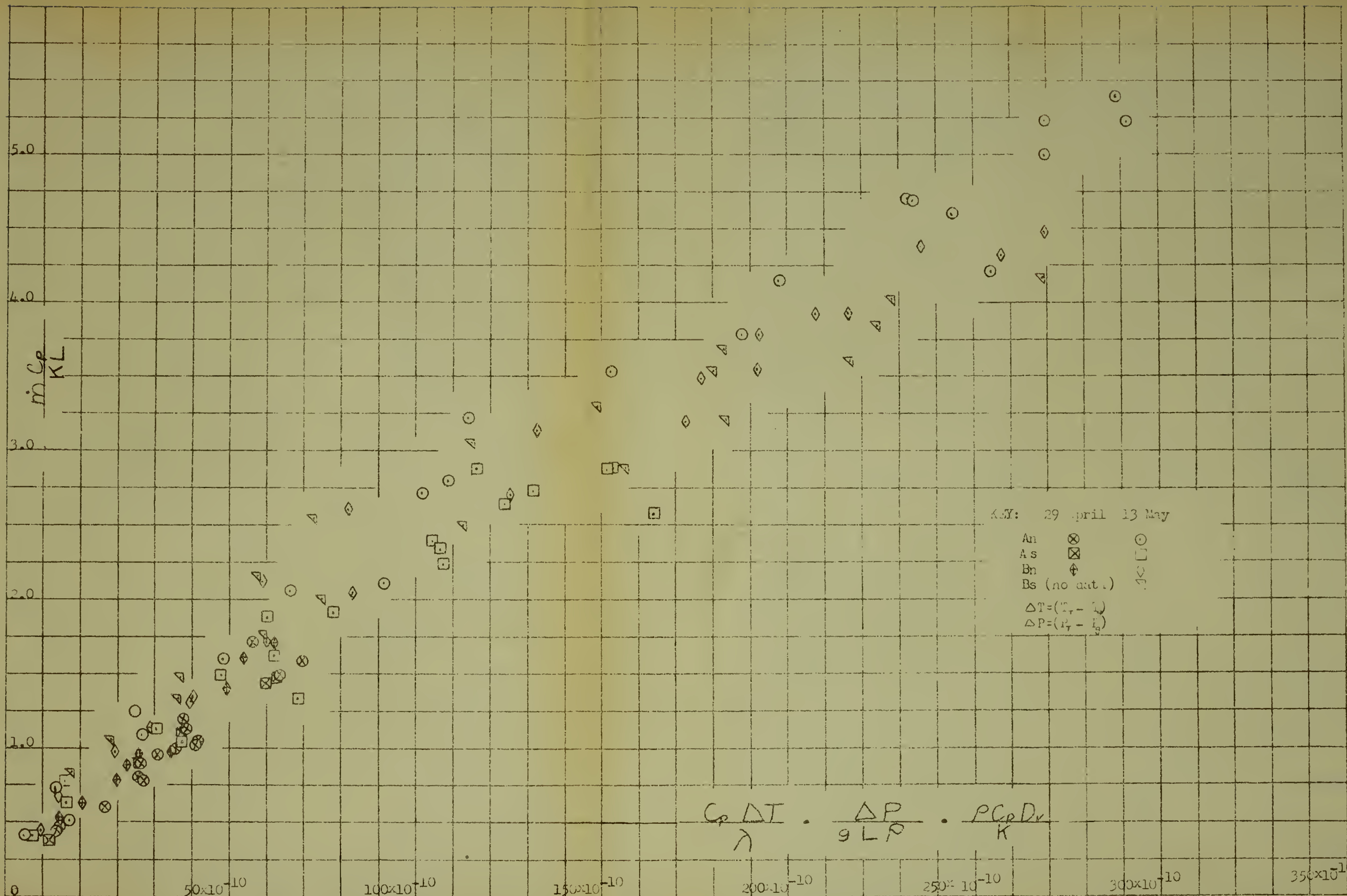

FIGURE (9) Pe VS. N (NORTH AND SOUTH CONDENSING SURFACES SEPERATELY)

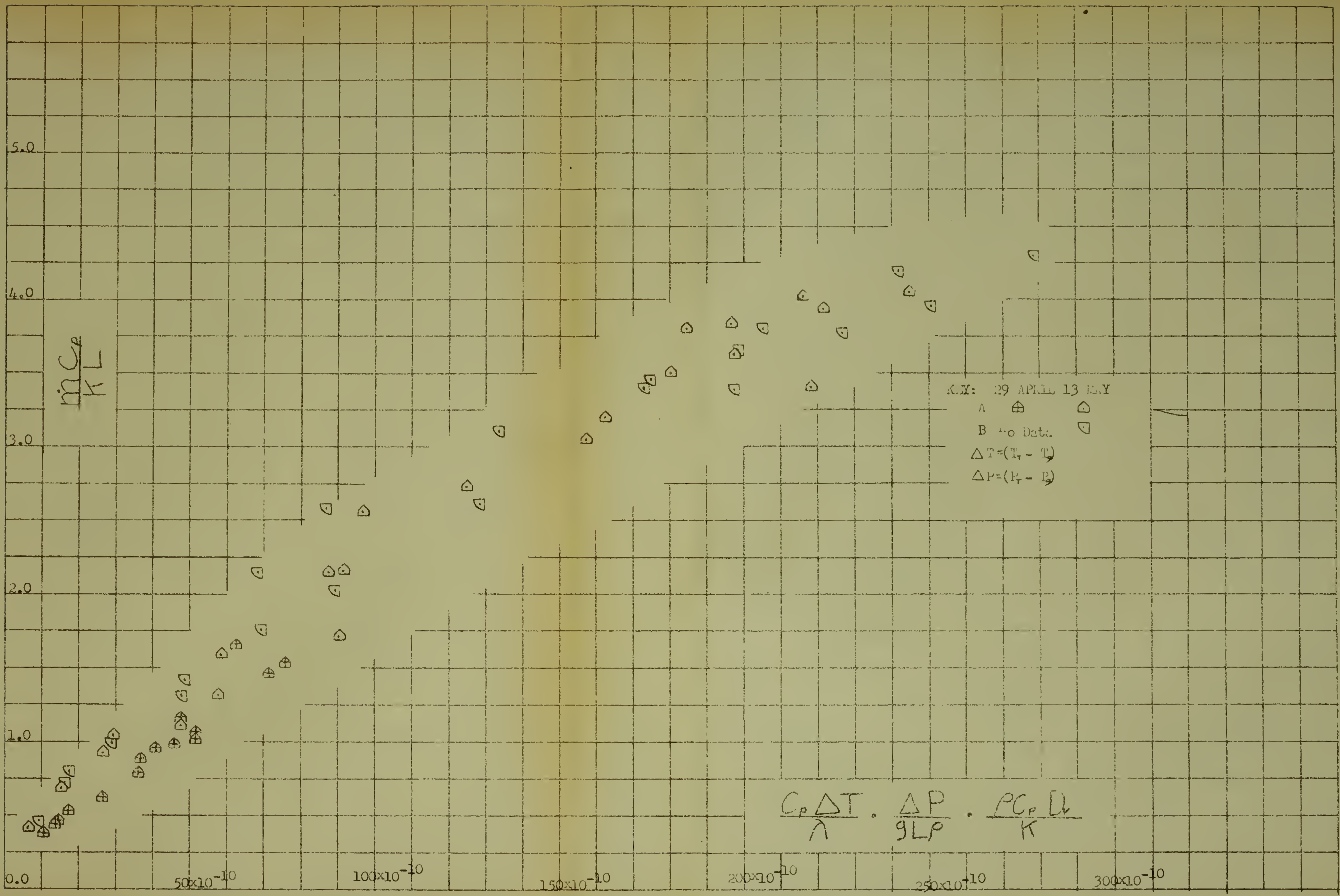

FIGURE (10) Pe VS. N (NORTH AND SOUTH CONDENSING SURFACES AVERAGED)

Comments.

1) The amount of correlation obtained was gratifying to the writer since here an attempt was being made to correlate data of an averaged nature (the mass flow rate) with data of a more instantaneous nature (the temperatures).

Tg is considerably affected by the wind, and in the afternoon when winds were usually stronger and gusty, the scatter caused by the sudden change in Tg was particularly noticeable.

2) The temperature information, even on the dates considered, showed some evidence of being faulty on Still "B". There were indications that the "loop" appearance of the plot of Bn and Bs might be due to faulty temperature readings in the afternoon. This possible trouble manifested itself in temperature readings, indicating that two adjacent terminal boards were three degrees different in temperature, a difference difficult to reconcile with observation of the boards.

Examination of the Parameter N.

Assuming at this point that there is a correlation between Pe and N, an examination of the factors causing the variation of N is indicated.

Still "B", 13 May, North Side

Time	(1) 0930 PDST	(2) 1330 PDST	Increase factor Col. 2 ÷ Col. 1
Pe	.784	4.465	5.7
N	777.7	2793	15.7
Tw	94.17	145.23	
Tg	78	110	
Tf	86	127.5	
ΔT	16.17	35.23	2.08
ΔP	.330	1.997	6.05
N'	3330	4010	1.20

Note: $N = N' \Delta T \Delta P$

Referring to the table above, we see that the most important factor in the rise of a solar still to maximum midday production, in terms of the variables considered, is the vapor pressure. Vapor pressure is however completely expressible in terms of temperature. If P were directly proportional to T then the increase in the P term would be the same as the ΔT increase factor, 2.08. The "extra factor", $\frac{6.05}{2.08} = 2.91$, can be attributed to the temperature variation. Grouping the temperature factors we then have $2.91 \times 1.2 = 3.5$. Similarly the ΔT factors $= (2.08)^2 = 4.325$, meaning that variation in ΔT is roughly a 20 percent greater factor on this particular day. However, on a hot day with low wind, the temperature factor would tend to increase, and the ΔT factor decrease.

Perhaps a more meaningful examination would be to examine the change

in Δ T necessary to offset a change in T. This requires a trial and error approach since Δ P is affected both by Δ T and T_f, and it is found that at 1330 if the film temperature is dropped ten degrees F. then Δ T must increase 4.8° to a total of 40°F. to maintain the same yield. In terms of the water temperatures and glass temperatures, if Tt drops ten degrees, Tg must drop 16.3° to maintain the same yield.

Interpretation of N - Pe correlation.

While the N - Pe correlation might be more complete if an interior glass temperature were used, this was avoided in an effort to find a correlation using the most easily measured important dependent variables. Since an exterior glass temperature was used it can be expected that if a thinner glass, or one with higher thermal conductivity were used, that the N - Pe curve would have a slightly greater slope.

It is believed that the N - Pe correlation is independent of efficiency, i. e., for a certain combination of water temperature and Δ T the mass flow rate will be determined.

It is hoped that the value of the above correlation lies in four regions which will be separately discussed.

1) In the method of variation of the parameter itself:

The fact that Δ T must increase sharply to offset a decrease in the water temperatures indicates the probable reason for the failure of the efforts to increase efficiency by increasing the capability of the condensing surfaces. While no method was found to measure the convection losses, due to inability to measure the insolation, it is considered a reasonable assumption that they vary as the 5/4 power of Δ T, in some close accordance with the usual formulas for the free convection

of air under a cooled flat plate, where $h = .27\left(\frac{\Delta T}{L}\right)^{.25}$. With this assumption, we see that any attempt to cool a solar still is likely to cause increased convection losses, since the overall effect of that cooling is to decrease the water temperature and increase the ΔT. We further see that such cooling would increase the efficiency of a still only in the operating region where the increase in convection losses is offset by a larger decrease in radiation and conduction losses. This probably occurs under some combinations of high ambient temperature, high insolation, and low wind velocities. It should seldom occur on the Monterey Peninsula, where the ambient temperatures rarely reach 70°F. Assuming the proportionality of our convection losses to the 5/4 power of ΔT, we see in the preceding example where the Tt was lowered ten degrees requiring the T_g to decrease 16.3°, that the ratio of the convection losses of the final and initial conditions becomes

$\left(\frac{135.23 - 93.7}{145.23 - 110}\right)^{5/4} = 1.23$, or a 23 percent increase in convection losses.

While it would be hazardous to say that the N - Pe correlation under discussion can be applied to a still using forced convection, probably some very similar correlation can be obtained. Daniels (4) outlines an experiment with a forced-convection type of still and concludes that the low efficiency (25 percent) was due to too rapid air movement which resulted in the air not being saturated. This writer is in agreement that the air circulation may have been too rapid, but suggests that perhaps the result was not unsaturated air, but rather a lowering of the system temperature, together with the attendant increased ΔT and convection losses.

Similarly noted in this same source (4) is a plastic lifeboat still developed by Telkes, which floats on the ocean surface. It is suggested

that this still might produce greater yield if it were lifted <u>out</u> of the water.

Fitzmaurice (16) indicates an increase of yield of 45 percent when a still with a diamond-shape cross-section, with the tray suspended in the center, was used instead of a conventional Las Salinas type. Although some of the increased yield no doubt is due to the lack of conduction losses, he attributes this increase to the enlarged condensing capabilities, and to check this assumption, he covered the lower surfaces of the diamond with insulating board, whereupon he noticed a "<u>small</u> but definite reduction in yield."

Examination of the included plot of brine temperature, ambient temperature and yield curves for the Las Salinas type gives strong indication that these stills were in fact operating under conditions where a reduction of the water temperature by increased condensing capability should increase efficiency. Ambient temperatures for these measurements were often above 100° F. It can be questioned, however, whether the diamond-shape stills in seasons other than the summer season reported on, will show increased efficiency beyond that due to reduced conduction losses alone.

As a corollary it would seem that an effort to <u>increase</u> the operating temperatures of a solar still should pay dividends, up to the point where the rising conduction and radiation losses overcome the effect of decreased convection losses.

If the above surmizes are correct, perhaps the most important conclusion to be drawn is that various operating locales require different still designs, and that perhaps there is no one best design for all locales and seasons.

2) The last paragraph serves to introduce the second major region where the N parameter may prove useful:

It is intuitively believed that the performance of a solar still is reflected in the relationship of the temperature of the water to the ΔT between water and condensing surface, particularly under conditions described by Howe (19) of low wind and high insolation, where the performance radically changes. Therefore, it is suggested that if other investigators can confirm, improve, and extend the correlation described here, a whole new method of solar still design and operation might be evolved about the parameter N which will allow designing a still for specific locales and ambient conditions.

Since N is a function of T and ΔT only, using the coordinates of ΔT and T, the family of constant N lines can be drawn.

Since a line of constant N is similarly a line of constant $\dot{m}$, then the N - Pe correlation permits relating in terms of T and ΔT, the actual instantaneous performance of a solar still to the theoretical maximum performance. That is, the actual operating point may be studied in relation to the theoretical maximum N curve.

It is considered possible, particularly where means are available to measure insolation, that further study might suggest a method of laying out upon these constant N curves the family of "maximum efficiency operating curves" for a solar still. As the film temperature and ΔT varied throughout the day, departure from these curves might indicate design or operating changes to bring about closer adherence to one of the curves of this family. The gradients to the family of N curves might be found to have some significance in this respect.

It is regretted that time is insufficient for this writer to pursue

this idea, but it is hoped its interest to other investigators might be such that it will in the future be proved or disproved.

3) The third region where the parameter N may prove of value is as a substitute for $\dot{m}$ in any correlation where $\dot{m}$ might be employed:

For example if efficiency is under consideration a study of $\frac{N}{Q}$ should prove as effective as a study of $\frac{\dot{m}\lambda}{Q}$ and have the great advantage that all quantities are instantly measurable, do not require consideration of prior or future measurements, as any determination of $\dot{m}$ generally does, and time lag within the system does not effect the correlation as it generally does with correlation of mass flow rate.

4) The fourth region where N may have value is in other related fields of heat transfer.

It is considered that not only can finer measurements, together with an inclusion of a "time lag" factor increase the correlation of N with Pe for a solar still, but it is expected that this parameter may find applications in other fields of heat transfer theory where mass transfer of condensable vapor from a noncondensable gas is considered.

While the writer is not sufficiently familiar with heat-transfer literature to say with assurance whether this parameter or one similar to it has appeared previously, he notes the comments of Klinkberg & Mooy (7) on the pressure parameter of N, $\left(\frac{P}{g\rho L}\right)$ to the effect that in all analogy theories published so far, the fore mentioned ratio is disregarded. While there may be excellent reasons unknown to this writer for this, it is hoped that this parameter has now found at least one useful application.

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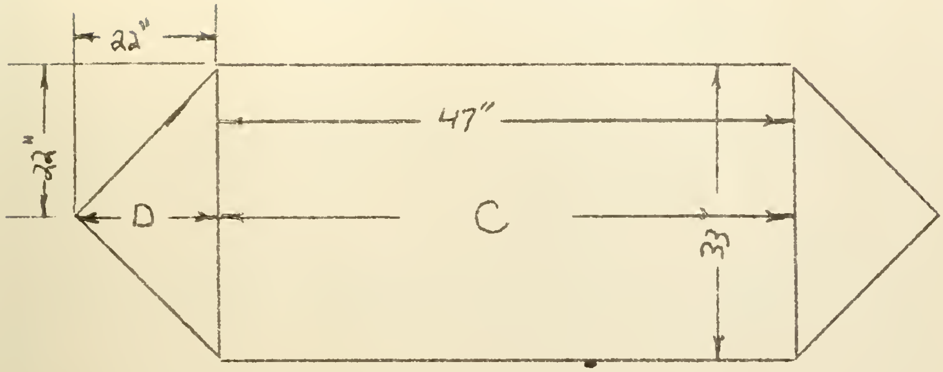
APPENDIX I

EXTERNAL ENERGY BALANCE FOR STILL "A"

at 1200 on 19 April, 1958



DEVELOPMENT OF ONE SLANT FACE AND 1/2 OF EACH VERTICAL END FACE.

Tt = 139° F.
Tg = 112° F.
T(dry bulb) = 64° F.
T(wet bulb) = 60° F.

Wind: 2.5 knots, 090°
$\dot{m}$ = 2.268 lbs/hr.
λ = 1014 BTU/lb.
Ag = 28.24 ft^2.
Ag less E and W faces = 21.52 ft^2.

Energy removed from still by wind:

$$Nu = \frac{q/W}{(Kair(Tg-Ta)} \qquad (12)$$

$$Nu = .592 \sqrt{Re} \qquad (2)$$

$$Re = \frac{V \cdot L \rho}{\mu}$$

$$L(effective) = C + 2(2/3D)$$
$$= 47/12 + 2(2/3) \frac{22}{12 \cdot \sqrt{2}} = 5.642 \text{ ft.}$$

$$\text{Effective width, } W = \frac{Ag}{L} = \frac{28.24 \text{ ft}^2}{5.642 \text{ ft}} = 5.01 \text{ ft.}$$

$$Nu = .592 \sqrt{\frac{(205 \cdot 1.689)}{.156} \cdot \frac{5.642}{10}} = 231$$

$$q/W = 231\ Ka(Tg - Ta)$$

$$= 231(.016)(112 - 64) = 177.3$$

$$q = 888\ BTU/Hr.$$

Energy removed from still by natural convection:

For a vertical plate: $h_c = .29\left(\frac{\Delta T}{L}\right)^{.25}$ (2)

For a heated horizontal plate: $h_c = .27\left(\frac{\Delta T}{L}\right)^{.25}$

Use: $h_c = .28\left(\frac{\Delta T}{L}\right)^{.25}$ for 45° plate.

L N & S = Slant height of face = 33 feet = 2.75 feet.

L E & W = 2/3 altitude = 2/3 22/12 = 1.22 feet.

L average (area weighted) = 2.38 feet

$$h_c = .28\left(\frac{\Delta T}{2.38}\right)^{.25} = .2255\,\Delta T^{.25}$$

$$q/A_g = hc\ T = .2255(Tg - Ta)^{1.25}$$

$$= .2255 \cdot (48)^{1.25}$$

$$= 28.64$$

$$\underline{q = 810\ BTU/Hr.}$$

Energy removed from still by radiation to sky:

For N and S faces only; assume zero for E & W faces.

$$q/A = T^4abs(.22 + .148 \cdot 10^{.068P})\ .85 \qquad (5)$$

Tw/Td = 60/64 ∴ Rel. humidity = 80 percent

∴ P = .24 PSIA = 12.44 MM Mercury

$T_g = 113^\circ F. = 45^\circ C = 318^\circ K$

$$q/A = .826 \cdot 10^{-11}(318^4)(.22 + .148 \cdot 10^{-.068 \cdot 12.44})\ .85$$

$$= .1735 \qquad = 38.4\ BTU/Hrft^2.$$

$A = 21.52\ ft^2$ $\qquad$ $q = 827\ BTU/Hr.$

Heat removed from still by conduction:

Bottom of still only, considered.
Bottom insulation, 2½" fiberglass blanket, assume K = .024

$$q/A = \frac{K(Tt - Ta)}{X} = \frac{.024 \cdot (75)}{\frac{2.5}{12}} = 8.65\ BTU/ft^2Hr.$$

$A\ Tray = 15.34\ ft^2$

$\underline{q = 133\ BTU/Hr.}$

Summation:

q wind	= 888 BTU/Hr
q convection	= 810 BTU/Hr
q radiation	= 827 BTU/Hr
q conduction	= 133 BTU/Hr
	2658 BTU/Hr

For sun at midday, reflection losses = 8 percent of incoming insolation,

$$Q\ total = \frac{2658}{.92} = \underline{2890\ BTU/Hr}$$

Collector area = $15.34\ ft^2$

Q, per unit area of collector = $\underline{188.2\ BTU/ft^2Hr.}$

$\dot{m} = 2.268 \cdot 1014 = 2300\ BTU/Hr$

= 150 BTU/Hr per unit collector area.

$$\text{Midday efficiency} = \frac{\dot{m}\lambda}{Q} = \frac{150}{188.2} = \underline{\underline{79.8\ \text{percent}}}$$

APPENDIX 2

Compilation of Results for

Sections 4 and 5

Key to Tables 1 and 2:

Column 1 Still identity.

2 Amount of water condensed per unit area by North face, lbs/ft^2.

Area North face each still = 10.78 ft^2.

3 Amount of water condensed per unit area by the South face, lbs/ft^2.

Area of South face of each still = 10.78 ft^2.

4 Amount of water condensed per unit area by the East plus West faces lbs/ft^2.

Area of East plus West faces = 6.72 ft^2.

5 Total yield per unit area of collector surface, lbs/ft^2.

Area of collector = 15.34 ft^2.

6 Coefficient of performance of Still "A": total yield "A" ÷ total yield "B".

7 Comments. Times indicate cooling period. OC indicates overcast.

TABLE I

Compilation of Results for

Section 4

Date	1	2	3	4	5	6	7
31 January	A	.266	.238	.254	.465	1.068	Thin overcast
	B	.270	.228	.195	.435		
4 February	A	.157	.134	.139	.264	1.00	90° overcast
	B	.162	.134	.130	.264		
5 February	A	.177	.139	.102	.267	.993	Clear until 1000, then overcast
	B	.168	.142	.116	.269		
6 February	A	.090	.078	.065	.147	1.03	Thick overcast
	B	.080	.081	.055	.143		
9 February	A	.348	.316	.221	.563	1.01	Broken clouds
	B	.357	.319	.205	.557		
10 February	A	.229	.180	.149	.352	1.003	Overcast until 1200, then clear
	B	.235	.174	.146	.351		
11 February	A	.224	.183	.158	.354	1.00	Broken overcast
	B	.220	.186	.158	.354		
9 March	A	.427	.319	.320	.663	.991	Clear day
	B	.483	.282	.301	.670		
11 March	A	.406	.320	.324	.652	1.006	Very thin overcast
	B	.412	.326	.295	.647		
18 March	A	.394	.306	.317	.632	.995	Thin overcast, thickening at 1415
	B	.398	.312	.308	.635		
22 March	A	.332	.285	.294	.562	.970	Thin haze
	B	.334	.306	.296	.580		
19 April	A				.910	.972	Clear, hot
	B				.934		

Average Coeff of Performance: 1.004

Table 2

Compilation of Results for

Section 5

Date		1	2	3	4	5	6	7
			North Face of Still A Cooled					
26 February	A	.482	.241	.219	.603	.951	1330-1600, over-
	B	.422	.314	.266	.634		cast after 1500
7 March	A	.428	.228	.220	.567	.970	0930-1700, over-
	B	.368	.285	.272	.584		cast after 1430
19 March	A	.493	.231	.210	.602	.945	0915-1700, medium
	B	.389	.322	.310	.635		overcast in P.M.
12 April	A	.705	.305	.254	.819	.940	0905-1700, clear
	B	.517	.453	.433	.872		Ta max. = 81°
13 May	A	.765	.437	.355	1.000	.929	0915-1845, max.
	B	.615	.588	.525	1.077		cooling flow -
							thin haze, clear
							after 1100
			Average Coefficient =			.947	
			South Face of Still A Cooled					
5 March	A	.244	.260	.183	.434	.910	0900-1530, over-
	B	.297	.242	.223	.477		cast after 1500
10 April	A	.355	.565	.296	.777	.903	0930-1700, over-
	B	.513	.443	.427	.860		cast after 1700
			Average Coefficient =			.907	
			North and South Faces of Still A Cooled					
6 March	A	.336	.326	.180	.544	.869	0900-1530, over
	B	.395	3.12	2.95	.625		cast after 1500
11 April	A	.526	.461	.187	.775	.880	0930-1705, clear
	B	.515	.452	.441	.878		Ta max. = 75°
			Average Coefficient =			.875	

APPENDIX 3

DATA SHEETS FOR

29 April and 13 May 1958

Tuesday 29 April   <u>No Cooling</u>

PDST	0930	1000	1030	1100	1130	1200	1230	1300	1330	1400	1430	1500
						A						
▽ N	22	18	24	24	27	30	36	49	55	56	59	55
▽ S	20	19	23	24	27	31	38	50	54	58	58	54
▽ EW	7	7	8	20	13	18	19	24	31	38	35	31
						B						
▽ N	21	20	23	23	28	31	39	47	57	57	59	53
▽ S	20	22	24	23	27	31	39	47	57	59	58	53
▽ EW	8	7	9	17	12	18	26	27	30	32	32	28
Wind:		270/4		310/4		270/9		290/7		300/7.5		290/5
Tw/Td:		50/53		50/54		51/56		53/59		52/57		51/56

Note: ▽ is in milliliters.

PDST	1530	1600	1630	1700	1730	1800	1830
					A		
▽ N	53	71	103	86	78	53	44
▽ S	54	67	93	83	74	52	46
▽ EW	39	38	51	46	38	33	25
					B		
▽ N	54	71	106	82	73	52	45
▽ S	54	69	95	79	73	51	44
▽ EW	29	35	51	43	37	27	22
Wind:		290/8	270/6	270/3		270/3	
Tw/Td:		54/59	55/60	54/58		52/56	

Heavy overcast until 1530

Clear with scattered clouds 1530 - 1700; thinner overcast after.

Tuesday 29 April Temperatures, in millivolts.

	A							B				
	2	3	4	5	6	7	11	2	4	5	6	7
0900	.65	.62	.63	.6	.89	.83	.49	.6	.6	.56	.87	.77
0930	.7	.66	.675	.65	1.0	.93	.5	.635	.65	.58	.95	.82
1000	.75	.71	.72	.7	1.09	1.02	.53	.69	.69	.63	1.02	.925
1030	.7	.7	.71	.69	1.11	1.00	.51	.64	.68	.62	1.045	.89
1100	.71	.695	.72	.68	1.12	.99	.53	.63	.68	.62	1.05	.905
1130	.74	.74	.79	.73	1.18	1.055	.56	.70	.75	.685	1.12	1.0
1200	.76	.76	.82	.74	1.285	1.16	.57	.73	.79	.70	1.21	1.03
1230	.805	.82	.875	.80	1.39	1.23	.61	.76	.85	.75	1.31	1.15
1300	.925	.93	.96	.90	1.495	1.38	.61	.85	.91	.81	1.415	1.26
1330	.865	.86	.93	.85	1.51	1.35	.56	.79	.885	.78	1.435	1.2
1400	.81	.82	.87	.79	1.48	1.275	.55	.73	.83	.72	1.41	1.12
1430	.85	.86	.91	.83	1.51	1.32	.565	.785	.86	.755	1.43	1.18
1500	.81	.81	.87	.79	1.445	1.275	.55	.72	.82	.72	1.38	1.09
1530	1.87	1.88	1.945	1.87	1.50	1.365	.61	.8	.88	.785	1.40	1.215
1600	1.00	1.04	1.13	1.02	1.72	1.62	.67	.91	1.045	.95	1.60	1.40
1630	1.095	1.135	1.19	1.135	1.73	1.655	.66	.94	1.08	.96	1.655	1.405

1700	.995	1.02	1.10	1.03	1.695	1.505	.65	.89	1.02	.88	1.57	1.31
1730	.88	.88	.94	.87	1.50	1.295	.655	.77	.86	.75	1.43	1.13
1800	.85	.85	.9	.85	1.415	1.25	.56	.745	.83	.745	1.32	1.095
1830	.76	.75	.79	.75	1.25	1.095	.54	.66	.72	.655	1.17	.97

KEY
(Temperatures in millivolts,
copper constantin)

2 Tn

3 Ts

4 Te

5 Tw

6 Tt

7 Tv

11 Ambiént

Tuesday 29 April A North

Time	Tt	Pt	Tn	Pg	Tf	N'	Pt-Pg	T		m	N	Pe
1000	1.09	.531	.75	.320	.920	3191	.211	14.46	18	.092	97.35	.3818
1030	1.11	.547	.7	.296	.905	3185	.251	17.44	24	.106	139.4	.4358
1100	1.12	.554	.71	.300	.915	3190	.254	17.44	24	.111	1111.3	.4648
1130	1.18	.603	.74	.316	.960	3210	.287	18.72	27	.124	172.5	.5188
1200	1.285	.697	.76	.326	1.023	3240	.371	22.34	30	.142	268.5	.6018
1230	1.39	.804	.805	.350	1.098	3277	.454	24.89	36	.187	370.3	.7761
1300	1.495	.922	.925	.420	1.210	3355	.502	24.25	49	.233	406	.9504
1330	1.51	.940	.865	.383	1.188	3324	.557	27.44	55	.245	508	1.013
1400	1.48	.902	.81	.351	1.145	3301	.551	28.51	56	.255	518.6	1.050
1430	1.51	.940	.85	.375	1.180	3319	.565	28.08	59	.253	526.6	1.042
1500	1.445	.865	.81	.351	1.128	3292	.514	27.02	55	.230	457.2	.984
1530	1.50	.928	.87	.386	1.185	3322	.542	26.80	53	.260	482.5	1.133
1600	1.72	1.227	1.00	.467	1.36	3421	.760	30.63	71	.396	796.4	1.585
1630	1.73	1.242	1.095	.535	1.413	3453	.707	27.02	103	.431	660	1.722
1700	1.695	1.189	.995	.463	1.345	3411	.726	29.78	86	.364	737.5	1.494
1730	1.50	.929	.88	.392	1.190	3324	.537	26.38	78	.289	470.9	1.195
1800	1.415	.831	.85	.375	1.133	3295	.456	24.04	53	.213	361.2	.8840

Tuesday 29 April A South

Time	Tt	Pt	Ts	Pg	Tf	N'	Pt-Pg	T		$\dot{m}$	N	Pe
1000	1.09	.531	.71	.300	.900	3183	.231	16.17	19	.092	118.9	.382
1030	1.11	.547	.7	.296	.905	3185	.251	17.44	23	.103	139.4	.4275
1100	1.12	.554	.695	.294	.908	3186	.260	18.08	24	.112	149.8	.4648
1130	1.18	.603	.74	.316	.960	3210	.287	18.72	27	.127	172.5	.5270
1200	1.785	.697	.76	.326	1.023	3235	.371	22.34	31	.152	268.1	.6308
1230	1.39	.804	.82	.359	1.105	3280	.445	24.25	38	.193	354	.8010
1300	1.495	.922	.93	.422	1.213	3337	.500	24.04	50	.229	401.1	.9504
1330	1.51	.940	.86	.380	1.185	3321	.560	27.65	54	.246	514.2	1.021
1400	1.48	.902	.82	.358	1.150	3303	.544	28.08	58	.255	504.6	1.058
1430	1.51	.940	.86	.380	1.185	3321	.560	27.65	58	.246	514.2	1.021
1500	1.445	.865	.81	.352	1.128	3293	.513	27.02	54	.237	456.5	.984
1530	1.50	.928	.88	.392	1.190	3325	.536	26.38	54	.266	470.1	1.103
1600	1.72	1.227	1.04	.494	1.380	3433	.733	28.93	67	.352	728	1.482
1630	1.73	1.242	1.14	.570	1.435	3468	.672	25.10	93	.387	585	1.606
1700	1.695	1.189	1.02	.48	1.358	3419	.709	28.72	83	.345	696.2	1.432
1730	1.50	.929	.88	.392	1.190	3324	.537	26.38	74	.277	470.9	1.150
1800	1.415	.831	.85	.375	1.133	3295	.456	24.04	52	.215	361.2	.8923

Tuesday 29 April B North

Time	Tt	Pt	Tn	Pg	Tf	N'	Pt-Pg	T		m	N	Pe
1000	1.02	.480	.69	.291	.855	3163	.189	14.04	20	.095	83.9	.394
1030	1.045	.498	.64	.269	.843	3158	.229	17.23	23	.101	124.6	.4192
1100	1.05	.501	.63	.265	.840	3157	.236	17.87	23	.112	133.1	.4648
1130	1.12	.554	.70	.296	.910	3187	.258	17.87	28	.130	146.9	.5395
1200	1.21	.629	.73	.310	.970	2315	.319	20.42	31	.154	209.4	.6391
1230	1.31	.721	.76	.326	1.035	3246	.395	23.40	39	.189	300	.7844
1300	1.415	.831	.87	.386	1.143	3300	.445	24.2	47	.229	355.4	.9503
1330	1.435	.855	.79	.341	1.113	3285	.514	27.44	57	.251	463.3	1.042
1400	1.41	.826	.73	.310	1.070	3262	.516	28.93	57	.255	486.9	1.058
1430	1.43	.849	.785	.339	1.108	3282	.510	27.44	59	.246	459.3	1.021
1500	1.38	.794	.72	.305	1.050	3253	.489	28.08	53	.235	446.7	.9753
1530	1.40	.815	.80	.347	1.100	3278	.468	25.53	54	.275	391.7	1.141
1600	1.60	1.054	.91	.410	1.255	3360	.644	29.36	71	.389	635.3	1.614
1630	1.655	1.130	.94	.429	1.298	3383	.701	30.42	106	.413	721.4	1.714
1700	1.57	1.014	.89	.398	1.230	3347	.616	28.93	82	.341	596.5	1.415
1730	1.43	.849	.77	.330	1.10	3278	.519	28.02	73	.275	476.7	1.141
1800	1.32	.732	.745	.318	1.033	3245	.414	24.46	52	.213	328.6	.8840

Tuesday 13 May North Cooled 0915 - 1845

PDST	0930	1000	1030	1100	1130	1200	1230	1300	1330	1400	1430	1500
A												
∇ N	29	89	133	172	213	240	272	290	290	280	266	252
∇ EW		12	17	39	54	61	77	93	100	100	97	83
∇ S	34	51	73	91	116	125	130	137	152	159	154	150
B												
∇ N	29	57	93	130	164	184	206	225	249	233	215	215
∇ EW		23	33	68	90	102	112	150	165	138	122	122
∇ S	29	63	98	121	151	165	188	207	230	220	203	203
Tw/Td:		54.5/59		55/61		55/60		59/60		57/65		57/65
Wind:	070/1	090/4		0		090/1		320/1/2		270/5		290/7-10

Very thin haze until 1200; clear after 1200.

Cooling water off
1145-1150

Note: ∇ is in milliliters.

PDST	1530	1600	1630	1700	1730	1800	1830	1900	1930	2000	Totals
						A					
∇ N	241	219	193	160	136	96	80	55	27	17.5	3751
∇ EW	73	71	60	38	40	25	20	13	10	5	1088
∇ S	148	132	112	95	81	64	50	42	27	18	2141
						B					
∇ N	198	183	159	128	108	83	62	46	30	18	3015
∇ EW	109	96	77	59	52	30	23	17	13	5	1606
∇ S	185	178	155	126	111	82	66	50	34	21	2886
Tw/Td:		55/62	55/62		55/62			57/62			
Wind:		300/4-7	300/5 gusty		290/5			270/2			

Cooling off
at 1845, 70 gallons used

Local Sunset, 2000

Tuesday 13 May North Cooled Temperatures, in millivolts.

	A									B					
	2	3	4	5	6	7	8	9	11	2	3	4	5	6	7
0900	.84	.72	.78	.84	1.125	1.16			.52	.81	.81	.85	.87	1.04	1.065
0930	.72	.96	1.02	1.04	1.33	1.42	.45	.55	.69	1.01	1.01	1.09	1.105	1.39	1.44
1000	.82	1.07	1.10	1.10	1.597	1.635	.43	.55	.67	1.178	1.20	1.23	1.25	1.72	1.73
1030	.912	1.235	1.3	1.3	1.790	1.83	.43	.58	.73	1.36	1.395	1.42	1.4	2.0	1.98
1100	1.04	1.34			1.970					1.535	1.575			2.22	
1130	1.145	1.445	1.455	1.43	2.125	2.06	.46	.76	.82	1.69	1.73	1.73	1.645	2.408	2.36
1200	1.2	1.58	1.51	1.49	2.21	2.15	.46	.78	.8	1.8	1.83	1.83	1.72	2.51	2.47
1230	1.213	1.675	1.575	1.525	2.27	2.24	.45	.73	.83	1.928	1.928	1.928	1.76	2.63	2.57
1300	1.25	1.68	1.55	1.515	2.315	2.27	.5	.81	.89	1.92	1.935	1.89	1.72	2.648	2.60
1330	1.22	1.592	1.47	1.455	2.325	2.244	.59	.86	.83	1.752	1.78	1.725	1.65	2.58	2.498
1400	1.168	1.495	1.51	1.50	2.26	2.19	.59	.92	.81	1.67	1.74	1.68	1.56	2.515	2.22
1430	1.275	1.608	1.548	1.528	2.25	2.08	.56	.86	.85	1.69	1.745	1.78	1.63	2.46	2.23
1500	1.203	1.528	1.49	1.51	2.228	1.99	.56	.8	.87	1.645	1.675	1.715	1.59	2.41	2.17
1530	1.14	1.4	1.453	1.364	2.21	2.01	.59	.78	.72	1.43	1.51	1.612	1.392	2.25	1.88
1600	1.095	1.37	1.44	1.34	2.07	1.9	.56	.79	.86	1.39	1.45	1.53	1.36	2.14	1.81
1630	1.124	1.36	1.38	1.41	1.928	1.73	.56	.82	.89	1.401	1.44	1.51	1.422	2.024	1.8
1700	1.08	1.77	1.31	1.765	1.87	1.585	.52	.72	.84	1.37	1.375	1.465	1.36	1.93	1.68

	A									B					
	2	3	4	5	6	7	8	9	11	2	3	4	5	6	7
1730	.93	1.06	1.15	1.06	1.751	1.445	.52	.77	.78	1.148	1.152	1.26	1.15	1.78	1.538
1800	.823	.912	.995	1.00	1.565	1.78	.58	.71	.68	1.002	1.035	1.106	1.064	1.60	1.425
1830	.798	.91	.95	.975	1.37	1.155	.6	.72	.65	.935	.945	1.05	1.026	1.427	1.308
1900	.768	.72	.87	.87	1.158	1.083			.55	.82	.772	.90	.90	1.203	1.158
1930	.705	.653	.73	.73	.98	.968			.55	.71	.685	.80	.773	1.05	.992
2000	.549	.539	.580	.565	.802	.718			.51	.55	.57	.604	.58	.81	.735

KEY
(Temperatures in millivolts,
copper constantin)

2 Tn
3 Ts
4 Te
5 Tw
6 Tt
7 Tv
8 cooling to
9 cooling from
11 Ambient

Tuesday 13 May A North (Cooled)

Time	Tt	Pt	Tn	Pg	Tf	N'	Pt-Pg	T	N	Pe
0930	1.33	.743	.72	.305	1.025	3241	.438	25.95	368.4	1.0763
1000	1.597	1.050	.82	.358	1.209	3335	.692	33.06	763	2.0590
1030	1.790	1.338	.912	.411	1.351	3415	.927	37.36	1182.7	2.7895
1100	1.970	1.660	1.04	.494	1.505	3515	1.166	39.57	1621.8	3.5337
1130	2.125	1.960	1.145	.573	1.635	3583	1.387	41.70	2072.3	4.1500
1200	2.21	2.179	1.2	.62	1.705	3632	1.559	42.97	2433.1	4.6811
1230	2.27	2.33	1.213	.63	1.742	3659	1.700	44.97	2797.3	5.2336
1300	2.315	2.45	1.25	.664	1.783	3690	1.786	45.31	2986.1	5.3918
1330	2.325	2.478	1.22	.638	1.773	3681	1.840	47.02	3184.7	5.2183
1400	2.26	2.293	1.168	.601	1.714	3638	1.652	46.46	2792.2	4.9916
1430	2.25	2.271	1.275	.687	1.763	3673	1.592	41.48	2425.5	4.7253
1500	2.228	2.222	1.203	.622	1.716	3640	1.600	43.61	2539.8	4.5137
1530	2.21	2.179	1.14	.570	1.675	3611	1.609	45.53	2645.3	4.2231
1600	2.07	1.865	1.095	.535	1.583	3573	1.330	41.48	1971.2	3.7787
1630	1.928	1.580	1.124	.558	1.526	3532	1.022	34.21	1234.9	3.2202
1700	1.87	1.473	1.08	.523	1.475	3495	.950	33.61	1115.9	2.7134
1730	1.751	1.275	.93	.422	1.341	3410	.853	34.93	1016.0	2.1062
1800	1.565	1.007	.823	.360	1.194	3327	.647	31.57	679.6	1.5842
1830	1.37	.783	.798	.346	1.084	3270	.437	24.34	347.8	1.2509
1900	1.158	.5825	.768	.330	.963	3212	.2525	16.59	134.5	.7251
1930	.98	.454	.705	.299	.843	3158	.155	11.70	57.27	.4059

Tuesday 13 May A South

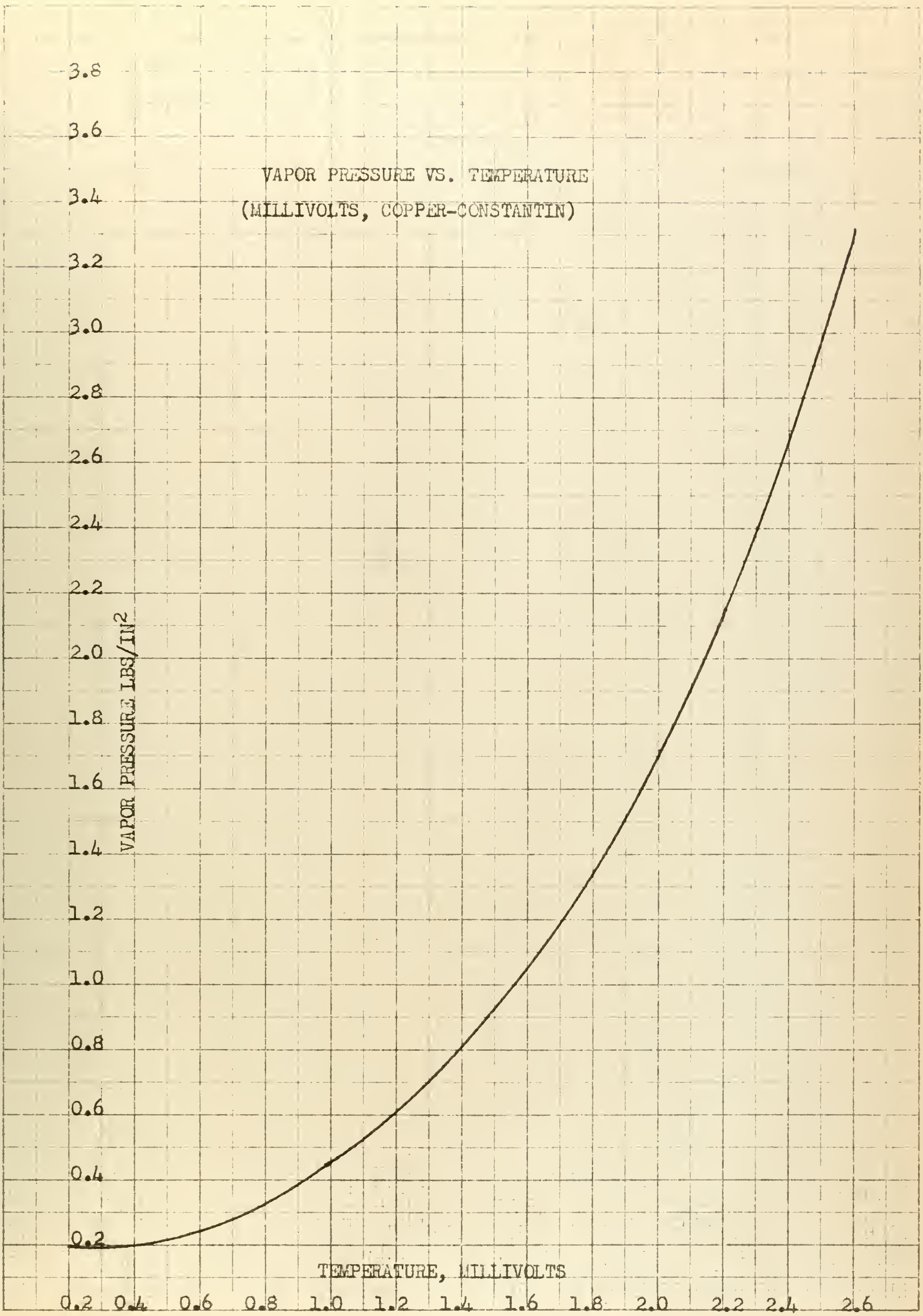
Time	Tt	Pt	Ts	Pg	Tf	N'	Pt-Pg	T	N	Pe
0930	1.33	.743	.96	.441	1.145	3300	.302	15.74	156.9	.775
1000	1.579	1.050	1.07	.516	1.334	3404	.534	22.42	407.5	1.131
1030	1.790	1.338	1.235	.651	1.513	3522	.687	23.61	571.3	1.493
1100	1.970	1.660	1.34	.752	1.655	3595	.908	26.80	874.8	1.904
1130	2.125	1.960	1.445	.863	1.785	3690	1.097	28.93	1171.1	2.231
1200	2.21	2.179	1.58	1.028	1.895	3775	1.151	26.80	1164.5	2.33
1230	2.27	2.33	1.675	1.158	1.973	3839	1.172	25.31	1138.8	2.423
1300	2.315	2.45	1.68	1.167	1.998	3860	1.283	27.02	1338.1	2.639
1330	2.325	2.478	1.592	1.042	1.959	3828	1.436	31.19	1714.5	2.870
1400	2.26	2.253	1.495	.921	1.878	3763	1.332	32.55	1631.5	2.875
1430		2.279	1.608	1.065	1.929	3801	1.214	27.31	1260.2	2.877
1500		2.222	1.528	.961	1.878	3761	1.261	29.78	1412.4	2.739
1530		2.179	1.40	.815	1.805	3705	1.364	34.46	1720	2.584
1600		1.865	1.37	.783	1.720	3643	1.082	29.78	1173.8	2.729
1630		1.580	1.36	.773	1.644	3589	.807	24.17	700.0	1.881
1700		1.473	1.27	.683	1.570	3564	.790	25.53	718.9	1.607
1730		1.275	1.06	.509	1.406	3490	.766	29.40	786.0	1.324
1800		1.005	.972	.45	1.270	3368	.558	25.31	475.7	1.027
1830		.783	.91	.410	1.140	3299	.373	19.57	240.8	.842
1900		.5825	.72	.306	.939	3200	.277	18.63	165.1	.632
1930		.454	.653	.275	.817	3147	.179	13.91	78.4	.410

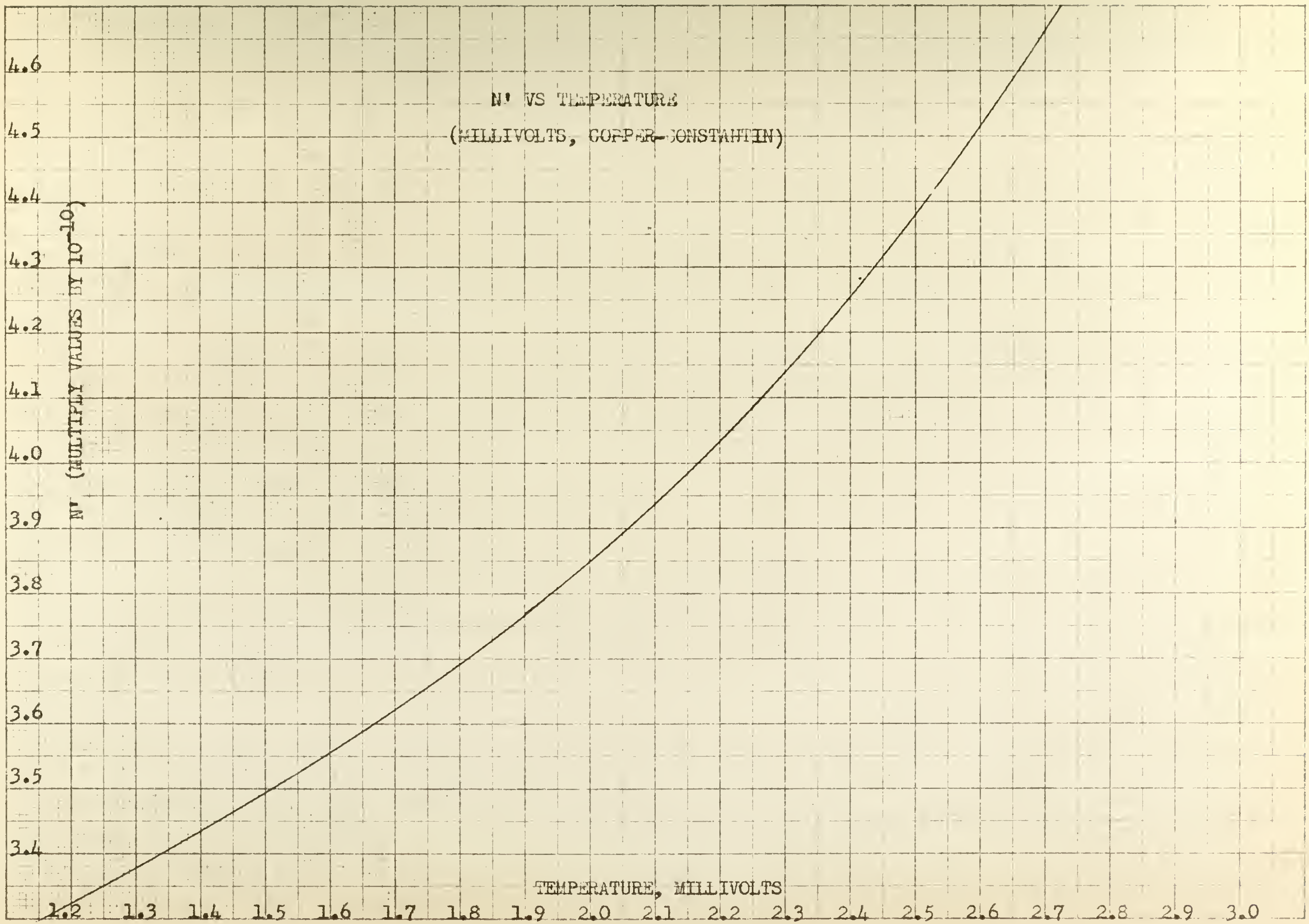
Tuesday 13 May B North

Time	Tt	Pt	Tn	Pg	Tf	N'	Pt-Pg	T	N	Pe
0930		.804	1.01	.474	1.200	3330	.330	16.17	177.7	.784
1000		1.226	1.178	.600	1.449	3477	.626	23.06	501.9	1.355
1030		1.72	1.36	.773	1.680	3614	.947	27.23	931.9	2.039
1100		2.20	1.535	.968	1.878	3761	1.232	29.14	1350.2	2.710
1130		2.715	1.69	1.181	2.049	3903	1.534	30.55	1829.1	3.195
1200		3.022	1.80	1.352	2.155	3999	1.670	30.21	2017.5	3.562
1230		3.421	1.928	1.58	2.279	4125	1.841	29.87	2268.4	3.932
1300		3.485	1.92	1.563	2.284	4131	1.922	30.97	2459	4.381
1330		3.252	1.752	1.275	2.166	4010	1.977	35.23	2793	4.465
1400		3.04	1.67	1.152	2.093	3942	1.888	35.95	2675.6	4.066
1430		2.87	1.69	1.181	2.075	3925	1.689	32.76	2171.8	3.925
1500		2.72	1.645	1.115	2.028	3882	1.605	32.55	2028.1	3.794
1530		2.28	1.43	.848	1.840	3740	1.432	34.89	1868.6	3.490
1600		2.015	1.39	.804	1.765	3676	1.211	31.91	1420.5	3.147
1630		1.768	1.401	.815	1.713	3638	.948	26.51	914.3	2.615
1700		1.583	1.37	.783	1.650	3593	.800	23.82	684.7	2.146
1730		1.32	1.148	.577	1.464	3483	.743	26.89	695.9	1.746
1800		1.053	1.022	.481	1.301	3386	.572	25.44	492.7	1.310
1830		.846	.935	.425	1.181	3320	.421	20.93	292.5	.979
1900		.623	.82	.358	1.012	3235	.265	16.29	139.7	.688
1930		.501	.71	.300	.880	3174	.201	14.46	92.3	.438

Tuesday 13 May B South

Time	Tt	Pt	Ts	Pg	Tf	N'	Pt-Pg	T	N	Pe
0930	1.39	.804	1.01	.474	1.200	3330	.330	16.17	177.7	.8390
1000	1.72	1.226	1.20	.620	1.460	3484	.606	22.12	467.0	1.4868
1030	2.0	1.72	1.395	.810	1.698	3627	.910	25.74	849.6	2.0073
1100	2.22	2.20	1.575	1.021	1.898	3777	1.179	27.44	1221.9	2.4973
1130	2.408	2.715	1.73	1.242	2.069	3920	1.473	28.85	1665.8	2.8960
1200	2.51	3.022	1.83	1.403	2.170	4130	1.619	28.93	1934.4	3.2156
1230	2.63	3.421	1.928	1.580	2.279	4126	1.841	29.87	2268.9	3.6067
1300	2.648	3.485	1.935	1.592	2.292	4140	1.893	30.34	2377.8	4.0343
1330	2.58	3.252	1.78	1.320	2.180	4230	1.932	34.04	2781.9	4.1698
1400	2.515	3.04	1.74	1.257	2.128	3974	1.783	32.97	2336.1	3.8472
1430	2.46	2.87	1.745	1.264	2.103	3950	1.606	30.42	1929.8	3.7087
1500	2.41	2.72	1.675	1.160	2.043	3896	1.560	31.27	1900.5	3.5534
1530	2.25	2.28	1.51	.940	1.880	3764	1.340	31.48	1587	3.3221
1600	2.14	2.015	1.45	.870	1.795	3697	1.145	29.36	1242.8	3.0741
1630	2.024	1.768	1.44	.859	1.732	3651	.909	24.85	824.7	2.5536
1700	1.93	1.583	1.375	.788	1.653	3595	.795	23.61	674.8	2.164
1730	1.78	1.32	1.152	.580	1.466	3489	.740	26.72	698.9	1.7638
1800	1.60	1.053	1.035	.491	1.318	3395	.562	24.04	458.7	1.3316
1830	1.427	.846	.945	.432	1.186	3322	.414	20.51	282.1	1.0591
1900	1.203	.623	.772	.332	.988	3224	.291	18.34	172.1	.7624
1930	1.05	.501	.685	.289	.868	3169	.212	15.53	104.3	.5016


VAPOR PRESSURE VS. TEMPERATURE
(MILLIVOLTS, COPPER-CONSTANTIN)
VAPOR PRESSURE LBS/IN^2
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
TEMPERATURE, MILLIVOLTS
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6



N' VS TEMPERATURE
(MILLIVOLTS, COPPER-CONSTANTIN)
N' (MULTIPLY VALUES BY 10-10)
TEMPERATURE, MILLIVOLTS
4.6
4.5
4.4
4.3
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0